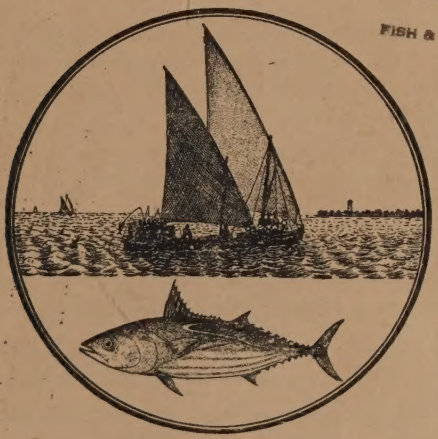
ES ODICAL
7(1)
7(1)

INDIAN JOURNAL OF FISHERIES

Vol. VII APRIL 1960 No. 1

LIBRARY
SEP 28 1961
FISH & WILDLIFE SERVICE



PUBLISHED BY

THE EDITORIAL COMMITTEE, INDIAN JOURNAL OF FISHERIES
FOR THE MINISTRY OF FOOD AND AGRICULTURE
GOVERNMENT OF INDIA

Price Rupees Four net

INSTRUCTIONS TO AUTHORS

1. Papers for publication should be sent to one of the members of the Editorial Committee at New Delhi, Calcutta or Mandapam Camp.

2. Papers forwarded for publication should ordinarily be in English. Scientific papers in Hindi or any other Indian language will also be considered for publication, as also papers in French and German. Papers in languages other than English should be accompanied by an adequate English summary. Papers forwarded to the Editorial Committee are understood to be offered to the *Indian Journal of Fisheries* alone.

3. MSS should be either typewritten (with double spacing) or written in legible hand on one side of the paper and the sheets properly numbered.

4. Each paper should include a summary, not exceeding one-twentieth of the text in length, giving a succinct account of the subjects covered, results obtained and conclusions drawn.

5. All tables of contents, references to plates, legends to illustrations in the text, etc., must be in their proper places with page and plate numbers left blank. The position in the text for the text-figures must be indicated. Foot-notes should be numbered in Arabic numerals.

6. All measurements should be given in the metric system; if other systems are used, the metric equivalents also should be given.

7. Archives for depositing bulky numerical data relating to papers published in the *Journal* have been created at the Central Marine Fisheries Research Station, Mandapam Camp, and at the Central Inland Fisheries Research Station, Calcutta. Only summarised versions of such data will be printed in the *Journal*.

8. All scientific names and popular names in Indian languages will be printed in italics and should be underlined in the typescript.

9. Photographs for reproduction must be clear, showing good contrast and printed on glossy paper.

10. Text-figures, line drawings and maps should be in Indian ink, preferably on Bristol board, with lettering also in ink. They should be on a larger scale to permit reduction to about two-thirds the linear dimensions of the original. A line of convenient length, drawn to scale, by the side of the figure itself should indicate the magnification of the camera lucida tracings. Graphs may be on squared paper ruled in *faint blue* lines or redrawn from squared paper on to tracing paper.

11. References to literature in text should be made by quoting the author's name and the year of publication, thus Day (1878) or (Day, 1878), according to circumstances, and adding the page number when necessary. References should be cited in full after the summary in the alphabetical order of the authors' names,

(*Contd. on Cover page* 3)

INDIAN JOURNAL OF FISHERIES

VOLUME VII, No. 1
Issued May 1960

Published by
The Editorial Committee, Indian Journal of Fisheries
for the Ministry of Food and Agriculture
Government of India

©

Price Rupees Four net

INDIAN
JOURNAL OF FISHERIES

VOLUME VII, No. 1
(June) May 1960

PRELIMINARY OBSERVATIONS ON THE SPAWNING OF INDIAN CARPS, INDUCED BY INJECTION OF PITUITARY HORMONES

By K. H. Alikunhi, M. A. Vijayalakshmanan and K. H. Ibrahim

(*Central Inland Fisheries Research Substation, Cuttack*)

Introduction

The cultivated and cultivable species of Indian carps generally breed in riverine habitats and, for rearing and stocking in ponds, their tiny young ones are collected in millions from the major rivers every year, during the monsoon months, June–August. These collections, however, invariably comprise a mixture of several species, a good many of which are unsuitable or undesirable for cultivation in ponds. As there is, at present, no dependable method for segregating the unwanted fish fry from the wanted ones at the early stage at which they are collected, the fish farmer is now obliged to rear the mixed lot of fry in nursery ponds and remove the unwanted species only when they have grown up to a distinguishable size. Considerable nursery space and appreciable expenditure for preparing the same have thus to be wasted for rearing these unwanted fry.

Though they do not breed in ordinary ponds, the Indian carps occasionally breed in what are called the 'Bundh' type of ponds which are generally minor irrigation tanks with large catchment area and subject to rapid flooding by rain-water from the catchment. However, the factors inducing spawning in these 'Bundhs' are obscurely known at present; breeding is also not regular every year and as such production of seed from this source is limited.

Fish culture in ponds is rapidly becoming popular in all the States in India, but the available supply of fish seed from natural sources is far from adequate to meet this growing demand. Besides, the seed has often to be transported over long distances from practically inaccessible and out-of-the-way collection centres to pond sites. Heavy mortality of fry during transport is also not uncommon. The need to induce the major carps to breed in confined waters and thereby ensure a dependable source of unmixed, pure quality fish seed is thus urgent.

Several observations have been made in India on the spawning of carps in their natural riverine habitats and also in the 'Bundh' type of ponds, but, as already mentioned, it has not yet been possible to specify the factor or combination of factors that actually induces the fish to spawn (Hora *et al.*, 1945; Ganapati and Alikunhi, 1950, Ganapati *et al.*, 1951; Alikunhi and Rao, 1951). Even an experienced 'Bundh' owner is not certain whether and when the fishes will breed in his 'Bundh'. Inducing spawning by injection of pituitary gland hormones has been successfully developed as a field method in Brazil (Cardoso, 1934; Von Ihering, 1937; Fortenele, 1955). Medium size riverine fishes of the families Characidæ and Doradidæ which ordinarily breed only once a year have been successfully induced to spawn in captivity by this method. In the United States Hasler *et al.* (1939, 1940), Palmer *et al.* (1954) and Ball and Bacon (1954) have successfully employed this method in several fishes. In India, as early as in 1938 Hamid Khan made an unsuccessful attempt to induce the major carp, *Cirrhina mrigala* to spawn by injecting specimens with the anterior lobe of mammalian pituitary glands. This is the only attempt so far made to induce an Indian carp to spawn by this method. In 1955, Chaudhuri (unpublished) at this Research Station succeeded in inducing the carp minnow *Esomus danricus*, to breed in laboratory aquaria by injecting distilled water extract of *Catla* pituitary gland. In 1956 (Chaudhuri, unpublished) the small riverine cat-fish, *Pseudeutropius atherinoides* was similarly induced to breed by administering pituitary gland extracts of *Cirrhina reba*. Ramaswamy and Sundararaj (1956, 1957) have induced breeding of the pond cat-fishes, *Heteropneustes fossilis* and *Clarias batrachus* in the laboratory by administering cat-fish pituitary extracts and also frog pituitary and mammalian chorionic gonadotrophins like Physex and Antuitrin S.

Concerted efforts to induce the Indian carps to breed by injections of pituitary gland hormones were made at this Research Station during June–August, 1957. Experimental work was organised at two centres, *viz.*, Cuttack and Angul in Orissa and a brief account of the results achieved has been given by Chaudhuri and Alikunhi (1957). As these experiments form the basis for further experimentation and standardisation of breeding techniques for the major Indian carps it is proposed to describe and discuss the same in detail. The work carried out at the Cuttack centre during 1957 is dealt with in this communication.

Age, Size and Care of Breeders

Only fish grown and matured in ponds were used in these experiments. The approximate age and size of the specimens used were as in Table I.

TABLE I

Particulars of carp breeders used for breeding experiments at Cuttack during 1957

Species	Age	Weight
Labeo rohita ..	3–4 years	4–9 lb.
Labeo calbasu	At least 2 years	½–1 lb.
Labeo bata ..	At least 2 years	¼–½ lb.

All the breeders were collected from the channel and stocking ponds in the Killa fish farm, Cuttack, in April and segregated in two ponds, each about an acre in area. Each pond contained about 200 fish of which 80% was *L. rohita*. There were two main size groups of *L. rohita*, the majority weighing 2–3 lb. and probably 2 years old, and about 10% weighing 4–9 lb. and probably 3–4 years old. Catla ranged from 5–16 lb. each and were approximately 2–4 years old; while Mrigals ranged from 2–5 lb. each.

The maximum depth of water in the two ponds in April was about 5 feet. From the third week of April the breeders in both the ponds were artificially fed every alternate day at the rate of 5 lb. of groundnut oilcake per pond. Depth of water was steadily falling in May, reaching the low level of 3·5–4 feet, when the majority of Catla, particularly the larger ones, died in the pond. Artificial feeding was temporarily suspended from the last week of May.

Periodic examination of the condition of the gonads showed some of the fishes with ripening gonads by the beginning of June. By the end of June males were found oozing when slight pressure was applied on the abdomen near the vent and the females had the abdomen soft and bulging with almost fully ripe ovaries. In the case of *L. rohita* almost all the larger specimens had reached the above stage, while in the smaller size-group only very few had developed mature gonads.

On 12th July 1957 the mature fish were netted out and the males and females were segregated and released in separate ponds which were dry during summer and which then had about 1·5 feet depth of recent accumulation of rain-water. The breeders in both the ponds were thereafter fed daily on cocoanut-oilcake. Within a week after segregating the sexes and keeping them in freshwater the maturity condition markedly improved,

the males becoming readily oozing and the females appearing fuller and more gravid than before.

Pituitary Glands and Injections

Fresh as well as preserved pituitary glands of *Labeo rohita*, *L. bata*, *L. calbasu* and *Cirrhina mrigala* were used in the various experiments. Pituitary glands from mature carps were collected during May–June, preserved in absolute alcohol and kept under low temperature in a refrigerator (Chaudhuri and Alikunhi, *op. cit.*). The glands were collected locally also as and when mature carps were taken from ponds for examination of their gonad conditions. Fresh glands for injection were dissected out just at the time of injection, from fishes killed a few minutes before.

The pituitary gland extract for injection was prepared invariably at the time of injection only. The preserved or fresh gland, as the case may be, was washed in distilled water and then finely ground in a little distilled water in a clean tube. The resulting pale white suspension was made up to the required volume by adding distilled water, allowed to settle for a few minutes and was then drawn carefully into a hypodermic syringe. The injections were given intraperitoneally by piercing the body wall at the angle between the pectoral fin and the body. For periodic injections the fish was carefully caught in a 'Chat jal' piece; laid on its side on a soft padding of netting cioth and held firm in that position. Large fish often struggle violently and injure themselves if they slip off from the soft padding. They are also likely to jump out while netting.

Injected fish were released in ponds, 70 feet × 70 feet to 150 feet × 70 feet in dimensions and with 1 foot–1½ feet depth of accumulated rain-water. Such ponds were, however, found somewhat inconvenient when the fishes were to be caught again for subsequent injections as the water easily got muddy and turbid by the dragging of the net. Further, the numerous aquatic insects and tadpoles that were present in these ponds were harmful to the eggs laid by the fish. In the majority of the experiments, therefore, the breeders, after injections, were released in cement cisterns containing a varying depth of fresh tap-water. Cisterns, 12 feet × 6 feet × 3 feet and 6 feet × 3 feet × 3 feet were successfully and repeatedly used. No running water was given in the cisterns. When the fish were given a second or third injection generally they were transferred immediately after injection to other cisterns containing fresh-water. When the weather became sunny and too hot water was occasionally sprayed from above and the cisterns were kept partially covered. As the injected fish sometimes became too active and started jumping the cisterns were ordinarily kept

covered with a large-meshed net. The water qualities in the ponds and the cisterns were generally as follows during the season:

TABLE II

Physico-chemical characteristics of tap-water and water in the Kila ponds, Cuttack, during July–August, 1957

Physico-chemical features	Pond-water (Kila ponds)		Tap-water in cisterns	
	Range	Average	Range	Average
Temperature (° C.) ..	26·5–35·0	32·36	30·5–33	31·25
pH ..	7·9– 9·0	8·36	6·8–7·3	7·0
Dissolved oxygen (p.p.m.) ..	3·6–11·2	6·96	5·8–7·2	6·1
Total alkalinity (p.p.m.) ..	78–156	112·4	64–110	80
Nitrates (p.p.m.) ..	0·06–0·15	0·085	..	..
Phosphates (p.p.m.) ..	0·4–1·2	0·75	Trace	Trace
Turbidity ..	40–800	140	Clear	..

EXPERIMENTS AND RESULTS

Several experiments were carried out with the major carps *Labeo rohita*, *Labeo calbasu* and *Cirrhina mrigala* and the medium size carp *Labeo bata*. Experiments relating to each of the above species are detailed separately in the succeeding pages.

Labeo rohita:

Particulars of the breeders injected during various experiments and details of injections given in each case are given in Table III.

Experiments 1 and 2 were carried out in the Kila farm. In the first experiment the fishes after the first injection were released in a pond with accumulated rain-water (depth 45–60 cm.). After the second injection they were transferred to another similar pond which had been partitioned by wire-netting into two to accommodate, under identical conditions, fishes from the second experiment also. The interval between the first and second injections was 16 hours and that between the second and the third

TABLE III

Particulars of Rohu (Labeo rohita) *breeders injected and details of injections given them during July–August*, 1957 *at Cuttack*

Expt. No.	Size of breeders		Nature of pituitary glands administered	First injection			Second injection			Third injection			Remarks
	Length (mm.)	Weight (kg.)		Date	Time	Dose per fish	Date	Time	Dose per fish	Date	Time	Dose per fish	
1	M 574	2·27	Freshly collected Rohu glands	18–7–1957	17·00	2 gl./2 c.c.	19–7–1957	9·00	3 gl./3 c.c.	19–7–1957	15·00	2 gl./2 c.c.	No spawning till 21–7–1957
	M 602	3·18		..	..	..	..	..	..	..	..	..	..
	F 581	2·72											
2	M 603	2·95	Preserved Rohu glands	19–7–1957	9·00	2 gl./2 c.c.	19–7–1957	15·00	2 gl./2 c.c.	Nil	Nil	Nil	Spawned during night on 19–7–1957
	F 586	*2·38											
3	M 616	4·08	,,	22–7–1957	13·45	2 gl./2 c.c.	22–7–1957	20·00	2 gl./2 c.c. for male only	Nil	Nil	Nil	Female was oozing eggs within 7 hours after the 1st injection
	M 490	1·59											
	F 570	2·50*											
4	M 550	2·04	,,	22–7–1957	13·45	2 gl./2 c.c.	23–7–1957	17·00	0·5 gl./0·5 c.c.	24–7–1957	9·30	1 gl./1 c.c.	Eggs laid between 15 and 17 hours on 24–7–1957
	M 581	2·50											
	F 543	2·04*											
5	M 552	2·04	,,	23–7–1957	17·00	0·5 gl./0·5 c.c.	24–7–1957	9·00	1 gl./1 c.c.	Nil	Nil	Nil	Spawning commenced within 6 hours of second injection
	F 450	1·13*											
6	M 592	2·90	,,	8–8–57	15·00	0·3 gl./0·3 c.c.	8–8–1957	19·00	0·3 gl./0·3 c.c.	9–8–1957	6·30	0·3 gl./0·3 c.c.	4th injection @ 0·25 gl./0·3 c.c. at 19 hours on 9–8–1957 had also no effect on the fish
	F 579	2·71											

* Weight after spawning. M—Male. F—Female.

was 6 hours. The males became freely oozing as a result of the first injection itself. Though each fish received a total dose of 7 fresh glands, in 7 c.c. of extract, in 3 injections, no spawning took place. In the second experiment Rohu pituitary glands, preserved in absolute alcohol for about 2 months, and kept in a refrigerator were used. The breeding environment was the same as in the first experiment. The interval between first and second injections was 6 hours. Within about 9 hours after the second injection the fishes spawned. The total dose was 4 glands in 4 c.c. extract, in 2 injections and spawning took place within 15 hours after taking the fish from the stock pond and administering the first injection. Laid eggs collected from the pond at 8 a.m. on 20–7–1957 had the embryos already moving inside and these hatched out within the next 10 hours.

The spawned female yielded a few more eggs on pressing the abdomen but dissection showed the ovaries baggy, blood-shot, shrunk and almost empty, indicating a fairly complete spawning. The male was freely oozing on applying very slight pressure near the vent.

The number of developing eggs found in the pond was, however, not commensurate with the size of the fish and extent of spawning as indicated by the condition of the ovaries. About a thousand eggs were collected for rearing in the laboratory but only a very small number of the eggs left in the pond survived to reach the fingerling stage. Numerous broken egg shells found in the water while collecting the eggs in the morning indicated that the majority of the eggs laid were somehow destroyed before hatching.

Because of the loss of eggs experienced in the pond subsequent attempts at inducing breeding were made in cement cisterns, providing tap-water to various depths. In experiment 3 the female was in oozing condition within 7 hours of the first injection of 2 glands in 2 c.c. extract. Though the male was given a second injection at the same dose as the first, spawning was not successful in the sense that the eggs laid were not fertilised.

In the fourth experiment, even though the female was smaller than that in the third, the first injection of 2 glands/2 c.c. extract did not induce spawning during the next 27 hours. A second injection of 0·5 glands/ 0·5 c.c. extract also did not produce positive results for the next 16 hours. However, within 6 hours of the third injection of 1 gland 1 c.c. extract spawning commenced. This fish therefore received a total dose of 3·5 glands, in 3·5 c.c. extract in 3 injections in the course of 43 hours, and spawning occurred 49 hours after the first injection. The laid eggs were fully swollen and nearly transparent. They appeared to be fertilized and early cleavage stages were observed. Development, however, did not

proceed further and within 2 hours of spawning the eggs gradually became opaque and died.

In the next experiment (No. 5) a smaller female was taken and an initial low dose injection of 0·5 gland 0·5 c.c. extract was given. Sixteen hours after, a second injection was given at double the dose of the first, and the fish started spawning within 6 hours. In this case, therefore, the total dose was only 1·5 glands, in 1·5 c.c. extract, in 2 injections and within 22 hours of the first injection the fish spawned. As in the earlier experiments the eggs were fully swollen and cleavage progressed up to the early morula stage beyond which development did not proceed. It is remarkable, however, that in this instance spawning occurred in a small cistern, 6 feet × 3 feet × 3 feet with just 1 foot depth of clear tap-water.

In the subsequent experiment the effect of still lower doses of injections was tried. A total dose of 1·15 glands, in 1·2 c.c. extract, administered in 4 injections during a period of 28 hours did not, however, yield positive results.

To find out whether an initial high dose of pituitary will yield positive results, a fresh experiment was set up in a cistern, 12 feet × 6 feet × 3 feet with 1 foot depth of water. The fishes measured as follows:

Sex	Length	Weight
	(m.m.)	(kg.)
Male ..	625	4·3
Female ..	592	3·4

When the initial high doses did not yield expected results further injections were given and in the course of 9 days the fishes received 10 injections as shown in table given on page 9.

The fishes did not spawn even after the 10th injection. During the period of observation each fish received a total dose of 10·5 Rohu glands, given at various intervals and doses. Weather conditions also widely fluctuated during the period, from very sultry and hot weather up to 30–7–1957 and then changing to cool, cloudy, rainy weather on 1–8–1957. After the initial high dose injections the fishes were quiet and did not show any excitement or activity for over 12 hours. 24 hours after the second injection they were fairly active, particularly the male. Similarly after the third injection also mild activity was observed, but thereafter the fishes remained quiet in spite of repeated injections.

Injection No.	Date	Time (hrs.)	Dose (gland/c.c. extract)	Remarks
1	25–7–1957	17·00	3·0/2·0	..
2	26–7–1957	7·15	2·0/2·0	14 hours after 1st injection
3	28–7–1957	8·30	0·5/1·0	49 hours after 2nd injection
4	29–7–1957	9·30	0·5/1·0	25 hours after 3rd injection
5	29–7–1957	15·30	0·5/1·0	6 hours after 4th injection
6	29–7–1957	22·30	0·5/1·0	7 hours after 5th injection
7	30–7–1957	5·30	0·5/1·0	7 hours after 6th injection
8	30–7–1957	13·30	1·0/1·0	8 hours after 7th injection
9	1–8–1957	6·30	1·0/1·0	41 hours after 8th injection
10	2–8–1957	8·30	1·0/1·0	26 hours after 9th injection

Labeo bata :

All the experiments with *Labeo bata* were carried out in tap-water in cement cisterns or aquaria. The breeders were netted from the stock ponds an hour or two before the first injection. Segregation of sexes prior to injections was not done. Details of injections given to different sets of breeders and the results obtained are given in Table IV.

In none of the above experiments the fishes were administered more than two injections. Of the three instances where successful spawning and fertilization of eggs took place two responded to single injections of $\frac{1}{3}$ and $\frac{1}{2}$ Rohu glands respectively per fish (expts. 1 and 6). In both these instances the fishes spawned within 10–12 hours after the injection. In the third instance (expt. 3) the first injection of $\frac{1}{2}$ gland did not induce spawning for the next 14·5 hours, but within 4 hours of the second injection spawning commenced. Repetition of successful doses of injections did not always produce expected results probably because the maturity conditions of the fishes differed slightly.

In a comparative study of the effectiveness of preserved Rohu pituitary glands and fresh as well as preserved Bata glands, the former induced spawn-

TABLE IV

Particulars of Labeo bata *breeders injected and details of injections given during July–August,* 1957 *at Cuttack*

Expt. No.	Length and weight of breeders			Nature of pituitary gland administered	First injection			Second injection			Remarks
	Sex	Length (mm.)	Weight (gm.)		Date	Time	Dose per fish	Date	Time	Dose per fish	
1	M M F	264 250 262	175 155 185	Preserved Rohu glands	19-7-1957	17·00	0·5 gl./0·5 c.c.	..	Nil	..	Spawned within 12 hours
2	M F	270 260	192 207	,,	29-7-1957	17·45	0·5 gl./1·0 c.c.	..	Nil	..	Did not spawn till 31-7-1957
3	M F	255 247	162 110*	,,	1-8-1957	17·45	0·5 gl./0·5 c.c.	2-8-1957	8·15	0·5 gl./0·5 c.c.	Spawned 4 hours after 2nd injection
4	M F	268 269	155 220	Preserved Bata gland	,,	17·30	1·0 gl./0·5 c.c.	,,	8·00	1·0 gl./0·5 c.c.	Did not spawn till 4-8-1957
5	M F	264 252	178 197	Fresh Bata gland	,,	17·15	1·0 gl./0·5 c.c.	,,	7·45	1·0 gl./0·5 c.c.	,,
6	M F	269 265	190* 138	Preserved Rohu gland	8-8-1957	18·30	$\frac{1}{3}$ gl./0·2 c.c.	..	Nil	..	Spawned within 10 hours
7	M M F	262 259 from set	172 165 5	,,	,,	18·00	$\frac{1}{3}$ gl./0·2 c.c.	9-8-1957	6·45	$\frac{1}{6}$ gl./0·3 c.c.	Did not spawn till 11-8-1957
8	M F	252 254	160 190	,,	27-8-1957	17·15	M 0·1 gl./0·2 c.c. F 0·15 gl./0·3 c.c.	28-8-1957	6·45	M 0·1 gl./0·2 c.c. F 0·15 gl./0·3 c.c.	Water temperature maintained at 24 to 26°C. No spawning took place within 24 hours after 2nd injection
9	M F	257 249	168 176	,,	,,	17·15	,,	,,	6·45	,,	Normal water temperature 28 to 30·5° C. No spawning within 24 hours of the 2nd injection
10	M F	269 251	190 185	,,	30-8-1957	17·15	M 0·4 gl./0·4 c.c. F 0·6 gl./0·6 c.c.	31-8-1957	8·00	M 0·2 gl./0·2 c.c. F 0·8 gl./0·3 c.c.	Fishes did not spawn

* Weight after spawning. M—Male. F—Female.

ing after a dose of 1 gland in 2 injections (expt. 3) while the latter (both preserved as well as fresh glands) at a dose of 2 glands in two injections did not induce spawning. The successful dose of 1 Rohu glands is much higher than the $\frac{1}{3}$ and $\frac{1}{2}$ glands that induced spawning in slightly large specimens. The two Bata glands, in bulk, would approximate to 0·5 Rohu gland but these did not induce spawning.

In experiments 1 and 6 the fishes spawned during the night, *i.e.*, during early morning hours. In experiment 3, however, even though the initial dose of pituitary was administered almost at the same time as in experiments 1 and 6 spawning occurred later, at noon, between 12 and 14 hours when the weather was hot, with bright sunshine. Similar spawning, during daytime, even under conditions of hot weather, was observed in the case of Rohu also.

Maintaining low water temperature in prevailing hot weather did not induce breeding even though the fishes received 0·2–0·3 Rohu glands in 2 injections (expts. 8–9), a dose which in one injection induced breeding in experiment 6.

In all cases where spawning was successfully induced, subsequent examination of the spawned female showed that spawning was complete and that the ovaries had shrunk into reddish-brown, baggy masses.

In almost all cases the injected fishes became excited and active within 2–4 hours of the first injection. In experiments 3, 4 and 5 the fishes were observed to be markedly active just 1·5 hours after the first injection. The males in some of these were seen jumping out of water repeatedly. In experiment 4 within a few minutes of the second injection the female became active and was seen touching and pushing the male with its snout. The fishes continued to be active even 4 hours after, though no spawning took place. Similarly in experiment 10 also within 4 hours of the first injection the female was restless and the male started jumping, but they did not spawn.

Collection of eggs for hatching.—The fertilised, fully swollen eggs have a light pale brown tinge. As the water level in the breeding cistern was low and as no running water was also provided the large number of eggs laid in the limited space had to be removed and kept elsewhere for successful hatching. If left undisturbed in the breeding cistern the eggs will die in the course of a few hours due to lack of adequate concentration of dissolved oxygen in the water. The eggs were therefore carefully collected with a piece of netting cloth, even before the embryo started movement and kept for hatching after the total number and percentage of fertilization were estimated by sampling, as follows:

TABLE V

Particulars of eggs laid and extent of fertilization in three specimens of Labeo bata *which spawned in cisterns as a result of pituitary injections*

Spawned female		No. of eggs laid	Percentages of fertilisation	Particulars of laid eggs		
				Total volume		Total weight after swelling
Length (mm.)	Weight (gm.)			Before spawning (c.c.)	After spawning (c.c.)	(gm.)
262	185	37600	81·0	24·07	644	729
247	110	24300	58·0	15·5	417	464
265	138	44060	62·0	28·3	767	868

Spawning occurred in fresh tap-water. No running water was provided. Under these conditions the percentage of fertilization ranging from 58 to 81 may be considered as quite satisfactory. There was slight variation in the extent of swelling of the laid eggs, the diameter of the fully swollen developing egg ranging from 3·0 to 3·3 mm. The freshly laid egg swells up to the extent of 26–27 times its volume to attain the above size. In terms of weight while approximately 23,000 of the fully swollen eggs weigh 1 lb. (0·45 kg.) the same number before swelling (ovarian eggs) would have weighed a little over half an ounce (18 gm.) (Alikunhi, 1956). According to Nazir Ahamed (1948) 7520 mixed carp ova (fully swollen developing eggs from river) weigh 1 lb. Eggs of major carps like Catla, Rohu and Mrigal are relatively much bigger than those of *L. bata* and besides, the artificial environment in which *L. bata* spawned might have had some effect on the extent of swelling of the eggs. The figures given by Khan (quoted by Nazir Ahamed, 1948) for the weight-number relationship of the laid, swollen eggs of Catla, Rohu and Mrigal are however confusing.

Hatching of Eggs.—Hatching of the eggs was also done in cement cisterns, provided with tap-water. No running water was provided but the depth of water was maintained at 2 feet level. A large *hapa* (cloth tank), 10 feet × 6 feet × 3 feet, made of thin markin cloth was fixed fully stretched in water. Smaller *hapas* (5 feet × 2 feet × 1½ feet) made of round-meshed mosquito netting were then fixed inside the large *hapa*, in such a way as to

have 1 foot depth of water inside (Plate I, Fig. 4). Eggs for hatching were spread over at the bottom of these smaller *hapas*. They hatched out within 15-18 hours of fertilization and the hatchlings wriggled out through the round mesh into the outer cloth *hapa*. The next morning the inner *hapas*, together with the egg membranes sticking to them, were carefully and gently lifted and removed. The hatchlings in the outer *hapa* were allowed to remain there for the next two days by which time they started active movement and were ready for stocking in nursery ponds.

Labeo calbasu :

In the case of *L. calbasu* also all the experiments were carried out in cement cisterns provided with tap-water. The breeders were not segregated sex-wise and injections were administered soon after collecting them from stock ponds. Details of injections given and the results obtained are summarized in Table VI.

It could be seen from Table VI that out of the six trials made only one was successful. In the other cases, though the fishes became active soon after administering the hormone, no spawning occurred. The dose of hormone which induced spawning in experiment 1, when repeated in subsequent experiments did not result in spawning. Lower as well as higher doses tried did not yield any conclusive results.

As in the case of *L. bata* and *L. rohita* increased sexual activity was exhibited by the injected specimens by frequent chasing of the female by the male; by the active one pushing the other with its snout and by frequent jumping out of water.

Laid eggs and hatching.—The fertilised, fully swollen developing eggs have a distinct brownish tinge and measure on an average 4·3 mm. in outer diameter. The egg proper has an average diameter of 1·2 mm. The particulars of eggs laid by the specimen that spawned on 23–7–1957 are as follows:

Spawned female: length	..	260 mm.
Weight after spawning	..	210 gm.
No. of eggs laid	..	34,970
Percentage of fertilization	..	88
Percentage of hatching (Tray samples)	..	96
Calculated total volume of laid, swollen eggs	..	1,398 c.c.
Calculated total volume of laid eggs, before swelling		32 c.c.
Total weight of eggs laid after swelling	..	1,102 gm.
Number of swollen eggs per lb.	..	14,412

TABLE VI

Particulars of Labeo calbasu *breeders injected and details of injections administered during July–August, 1957 at Cuttack*

Expt. No.	Size of breeders		Nature of pituitary gland administered	First injection			Second injection			Remarks
	Length (mm.)	Weight (gm.)		Date	Time	Dose per fish	Date	Time	Dose per fish	
1	M 312†	487	Preserved Rohu glands	22–7–1957	19·00	0·5 gl./0·5 c.c.	Nil	Nil	Nil	Spawned within 8 hours of the first injection. Eggs fertilised
	F 260	210*								
2	M 312†	481	,,	23–7–1957	17·00	,,	Nil	Nil	Nil	Female was missing from the cistern in the morning but had not spawned. Male was the specimen that spawned on 22–7–1957 night and was freely oozing
	F 284	317								
3	M 272	295	,,	29–7–1957	17·15	0·5 gl./1 c.c.	Nil	Nil	Nil	No spawning till afternoon on 30–7–1957. The fish were restless and active in the morning, about 12 hours after the injection
	F 268	262								
4	M 312†	473	,,	,,	17·30	0·33 gl./0·66 c.c.	Nil	Nil	Nil	
	F 247	212								
	F 270	270								
5	M 284	292	,,	2–8–1957	20·45	0·5 gl./0·5 c.c.	..	..	..	No spawning till evening on 3–8–1957
	F 275	284								
6	M 269	240	,,	7–8–1957	17·45	0·3 gl./0·4 c.c.	8–8–1957	6·00	0·3 gl./0·4 c.c.	Males active; female quiet, about 12 hours after injection. 5 hours after 2nd injection male very active; female slightly. No spawning till 10–8–1958, though female remained fairly active on 9–8–1957
	M 281	282								
	F 282	300								
						3rd injection	8–8–1957	18·00	,,	
						4th injection	9–8–1957	6·00	0·5 gl./0·4 c.c.	

* After spawning. † Same male. Oozing from 22–7–1957 to 1–8–1957.

The eggs are appreciably larger and heavier than those of *L. bata*. The extent of swelling is also higher and this will largely account for the heavier weight. The percentage of fertilization of the eggs was good and both in trays as well as in *hapas* hatching was excellent. On the 2nd day after hatching there was however heavy mortality of fry in the *hapas* while the samples in trays were unaffected. On the 3rd day after hatching the surviving fry were ready for stocking in nursery ponds.

Cirrhina mrigala :

Only one pair of Mrigals was injected but these did not spawn. The reaction of these specimens to injections were, however, peculiar. They were netted out from stock pond on 23-7-1957 and transferred to cement cisterns with 1 foot depth of tap-water, after administering the first injection of 0·5 Rohu gland in 0·5 c.c. extract. The female weighed about 3 lb. and was appreciably bigger than the male. There was no segregation of sexes prior to administering the hormones. The fishes, left overnight, did not spawn for the next 15 hours. A second injection (1 Rohu gland/1 c.c. extract) was given at 9 a.m. on 24-7-1957, 16 hours after the first. Within 2 hours of the second injection the female became very active. It started jumping out of water frequently and was also chasing the male which remained quiet. It frequently pushed the male with its snout and was seen to be quite restless. This continued for the next 4 hours when they were transferred to freshwater in another cistern. The female remained active but even a third injection did not induce spawning.

Discussion

Inducing successful spawning of the major Indian carps in confined waters by administering pituitary hormones is an important landmark in the history of Fish Culture in the East, and opens up an entirely new field for selective breeding of cultivable fishes and progressive fish farming. Though several factors have been ascribed as prerequisites for inducing spawning of Indian carps in their natural habitats, the experiments detailed in the present paper have clearly shown that when the correct dose of hormone is administered the fishes breed even under artificial conditions. It is remarkable that successful spawning of Rohu, Calbasu and Bata was induced in the very limited space of small cement cisterns (6 feet × 3 feet × 3 feet); that spawning, fertilization of eggs, development and hatching occurred in fresh, perfectly clear tap-water and that no current or running water was essential to induce spawning. Though these might not be the ideal conditions to induce maximum spawning, it is indicated that under

the influence of hormones successful breeding is possible in a variety of environmental conditions.

It may be pointed out that by administering the hormones the fishes get the incentive to spawn naturally in the environment provided. In other words, spawning and fertilization of eggs are natural processes as the injected female lays eggs in the water and the male fertilises them normally. The method therefore is quite different from artificial insemination.

An important point that becomes obvious on a perusal of the experiments reported is that successful results are not predictable yet. Even repetition of successful doses did not produce positive result in several instances. It is possible that these anomalies are due to (1) differences in the state of ripeness of the gonads in the different specimens injected, and (2) the correct dose of hormones required for inducing ovulation not being available due to differences in the size of pituitary glands used and possibly due to differences in the hormone content of the glands collected from fishes in various stages of maturity and size. While standardisation of the size of pituitary glands in relation to the size and stage of maturity of the donor fish is possible, determining the stage of maturity of the female breeder to be injected is now entirely arbitrary. These are important problems which call for intensive experimentation before a dependable technique for induced breeding is evolved.

The reaction of the breeders to injection has been rapid and in certain instances spawning was induced by a single injection. Of the 8 instances of spawning reported in this paper, 4 were induced by single injection and only in one case a third injection was required to induce spawning. The time taken to induce spawning was also short, ranging from 7 to 12 hours for those which required only a single injection; 15–22 hours for those which required 2 injections and 49 hours in the case of the one which received 3 injections. These observations are not in full accord with those reported from Brazil (Fontenele, *op. cit.*) and America (Bail and Bacon, *op. cit.*).

The dose of injections required to induce spawning varied and no conclusions can be drawn at present from the limited number of successful instances recorded. No species or sex specificity of glands was, however, noticed in inducing spawning. The time of spawning also varied, in certain instances spawning occurring during daytime, in bright sunshine. Segregation of sexes prior to injections was not always done and still spawning was induced. The injected specimens, particularly the spawning ones exhibited considerable activity and also sexual excitement (Plate I, Figs. 2-3). In several instances within $1\frac{1}{2}$–2 hours of receiving an injection the

fishes became markedly active. They started actively swimming about in the water, appeared to the excited and restless and frequently tried to jump out. The more active one often chased the other about and if it did not respond, could be seen nosing it or pushing it with its snout (Plate I, Fig. 3). When both were active the male usually followed the famale without allowing it to rest at any place. During and immediately before spawning the female often abruptly stops swimming, moves in a jerky manner and then swims backwards without turning. This is a characteristic spawning movement. It was possible to observe these movements only because the fishes were breeding in clear shallow water in cisterns. In the natural pond or riverine habitat with the turbid flood-water it should be extremely difficult to clearly observe the actual spawning movements of breeding fish, though breeding male carps in 'Bundh' type of ponds have been reported as coiling round the body of the female. No such behaviour was observed in the present case. Since fishes are induced to breed in the very limited space of the cisterns, or similar enclosures it is necessary to remove the developing eggs to more spacious surroundings so as to ensure normal development and hatching. Proper technique for satisfactory hatching of the laid eggs has yet to be developed to make induced breeding of carps a complete success.

Summary

Experiments carried out during July–August, 1957 at Cuttack, to induce the Indian carps to breed under the influence of fish pituitary extracts administered intraperitoneally are described.

Successful spawning, including normal fertilization and hatching of eggs, was achieved by this method in *Labeo rohita*, *Labeo calbasu* and *Labeo bata*.

The spawning environment was fresh pond-water in one instance, and tap-water in the rest. No flow of water was provided to induce spawning.

Pituitary glands of *Labeo rohita* (sexes mixed) preserved in absolute alcohol, induced spawning in all the three species mentioned above. The successful dose varied from 1·5 to 4·0 pituitary glands for *L. rohita*; 0·33 to 1·0 gland for *L. bata* and 0·5 gland for *L. calbasu*.

Ordinarily not more than two injections were required to induce spawning. In several cases a single injection induced spawning, within a period of 7–12 hours.

Particulars of eggs laid, percentage of fertilization and hatching in respect of *L. calbasu* and *L. bata* are given. The eggs of all the three species were successfully hatched and the hatchlings grown in ponds.

Acknowledgements

Our grateful thanks are due to Dr. B. S. Bhimachar for his kind interest in this work and also for carefully going through the manuscript of this paper. We are also thankful to the staff of the Cuttack Substation for help rendered to us during various stages of this work.

References

Alikunhi, K. H. 1956 .. Observations on the fecundity, larval development and early growth of *Labeo bata* (Hamilton). *Ind. Jour. Fish.*, **3**, 216–29.

——— and Nagaraja Rao, S. 1951 Notes on the early development, growth and maturity of *Cirrhina reba* (Hamilton). *J. Zool. Soc. India*, **3** (1), 85–98.

Ball, R. C. and Bacon, E. H. 1954 Use of pituitary material in the propagation of minnows. *Prog. Fish. Cult.*, **16** (3), 108–14.

Burrows, R. E., Palmer, D. D. and Newman, H. W. 1952 Effects of the injected pituitary material upon the spawning of Blueback Salmon. *Ibid.*, **14** (3), 113–16.

Cardoso, D. M. 1934 .. Relacao genito-hipofisaria reproducaones peixes. *Areb. Inst. Biol.* (*S. Paulo*), **5**, 133–36.

Chaudhuri, H. and Alikunhi, K. H. 1957 Observations on the spawning in Indian carps by hormone injection. *Curr. Sci.*, **26** (12), 381–82.

Chaudhuri, H. 1955 .. Induced spawning of the carp minnow, *Esomus danricus* (unpublished).

———. 1956 .. Induced spawning of the riverine cat-fish *Pseudeutropius atherinoides* and notes on its early development (unpublished).

Fontenele, O. 1955 .. Injecting pituitary (Hypophyseal) hormones into fish to induce spawning. *Prog. Fish. Cult.*, **17** (2), 71–75.

Ganapati, S. V. and Alikunhi, K. H. 1950 Notes on the spawning of carps in the Thungabhadra in response to off-season freshets. *J. Zool. Soc. India*, **2** (2).

———, ——— and Thivy, F. 1951 On an interesting case of carp spawning in the River Cauvery at Bhavani, during June 1947. *Jour. Bombay Nat. Hist. Soc.*, **50** (1), 140–46.

Hamid Khan. 1938 .. Ovulation in fish. *Curr. Sci.*, **7** (5), 233–34.

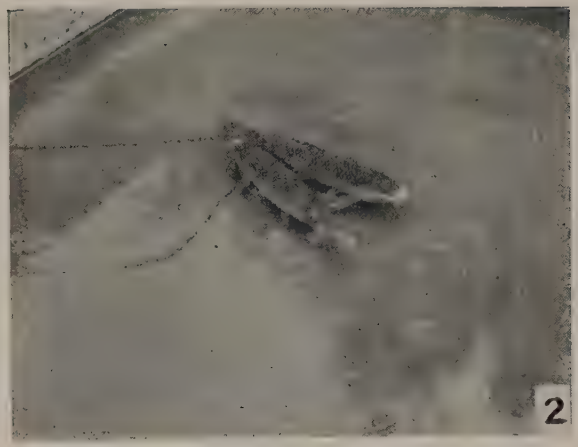
Hasler, A. D., Meyer, R. K. and Field, H. M. 1939 Spawning induced prematurely in trout with the aid of pituitary glands of carps. *Endocrinology*, **25** (6), 978–83.

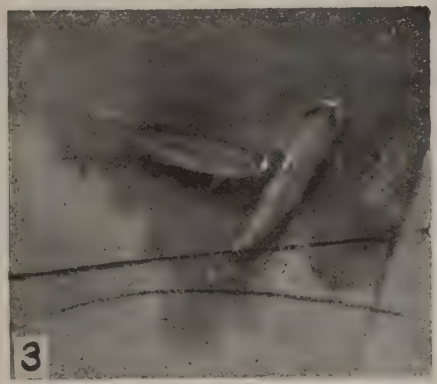
———————. 1940 .. The use of hormones for the conservation of the muskelinge *Esox masquinoney immaculatus* Garrard. *Copeia*, (1), 43–46.

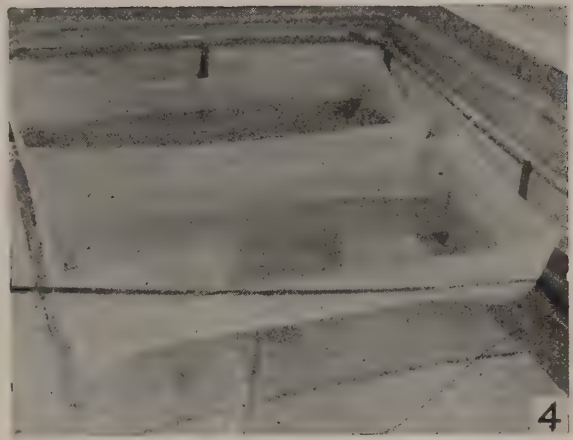
Hora, S. L., *et al.* 1945 Symposium on the factors influencing the spawning of Indian carps. *Proc. Nat. Inst. Sci. India*, **11** (3), 303–12.

Nazir Ahamed. 1948 A note on carp ova and their hatching. *Curr. Sci.*, 362–63.

Palmer, D. D., *et al.* 1954 .. Further studies on the reactions of adult Blueback Salmon to injected salmon and mammalian gonadotrophins. *Prog. Fish. Cult.*, **16** (3), 99–107.







FIGS. 1–4. Fig. 1. Injecting a female specimen of *Labeo rohita* with pituitary gland extract.
Figs. 2 and 3. An injected pair of *Labeo rohita* in clear water in a cement cistern. Larger one is the male. The female has become active and can be seen pushing the male with its snout.
Fig. 4. Hatching 'hapas' fixed in a cement cistern filled with clear tap-water.

Ramaswamy, L. S. and Sundaraj, B. 1956 .. Induced spawning in the Indian cat-fish. *Science*, **123** (3207), 1080.

———. 1957 .. Some aspects of induced spawning in the cat-fish *Heteropneustis*. *Sondor. Naturwiss.*, H.2, S. 46, Jatrg. 44.

———. 1957 .. Induced spawning in the cat-fish *Clarias*. *Ibid.*, H. 13, S. 384, Jahrg. 44.

EXPERIMENTS ON INDUCED SPAWNING OF INDIAN CARPS WITH PITUITARY INJECTIONS

By Hiralal Chaudhuri

(Central Inland Fisheries Research Station, Cuttack)

Introduction

One of the main problems confronting the progress of pisciculture in India is the dearth of fish seed of cultivated species of fishes for stocking ponds, tanks and reservoirs all over the country. The Indian carps, which are the main cultivated fishes, do not normally breed in confined waters although they attain maturity in such waters. They breed in riverine habitats and it is an age-old practice amongst fishermen to collect, from the rivers in North-Eastern part of India in specially designed nets, fertilised eggs and newly hatched larvæ (spawn) which drift along in river margins. The spawn thus collected is usually a mixture of economic and uneconomic species of fishes. Often the percentage of economic variety is low. As at present there is no means of sorting the different varieties at this stage the fish farmer has to take a chance and is quite often disappointed with the result. Besides this method involves effort of collection, transport, mortality during transport, high cost involved and above all uncertainty of availability of spawn or fry at the required time.

To meet the shortage of fish seed, great need was felt by Fish Culturists to make attempts towards studying the factors responsible for spawning of carps so as to induce these to breed in confined waters (Hora, 1945).

It is well known that the pituitary glands of higher vertebrates influence sexual maturity in animals, but till recently, information regarding the role of pituitary gland in the control of sexual development in fishes was meagre. Studies on the effect of hormone on the reproduction of fishes were therefore mostly carried on with hormones of mammalian origin and a few synthetic hormones (Young and Bellerby, 1935; Owen, 1936; Johnson and Riddle, 1939; Berkowitz, 1941; Eversole, 1941; Baldwin and Li, 1942). The results were not very encouraging. Subsequent experimental data show the relatively higher efficiency of fish pituitary extracts over those of mammalian origin when injected into fishes.*

* The available literature on the physiology of the pituitary glands of fishes and their effect on the reproduction of fishes has been reviewed by Atz (Pickford and Atz, 1957) and Hoar (1957).

The Brazilian Pisciculturists were the first to use fish pituitary extracts in such work and they succeeded in inducing spawning in their indigenous fishes for the first time in early thirties (Houssay, 1931; Cardoso, 1934; Pereira and Cardoso, 1934; Ihering and Azevedo, 1934). The Russians have also succeeded in developing a technique of breeding Sturgeons from the year 1937 (Gerbil'skii, 1938; Kazanski, 1939). Since then, experiments on pituitary treatment of fishes had been successfully tried in the United States (Hasler *et al.*, 1939; Burrows *et al.*, 1952; Ball and Bacon, 1954; Combs and Burrows, 1959), Japan (Fugita *et al.*, 1946; Kawamura and Motanaga, 1950; Kawamoto, 1950) and a few other countries (Oordt and Bretschneider, 1941; Vivien, 1939). A large number of investigations have been carried out in the above-mentioned countries on the physiology of pituitary gland and its role on the reproduction of fishes (Mathews, 1939). But excepting a few instances (Kawajiri *et al.*, 1948; Migita *et al.*, 1952; Pliszka, 1951) there had been very little attempt to apply pituitary hormone treatment to effect improvement in fish culture. It is only in Brazil and Russia, the method of inducing breeding by pituitary injections has become a regular part of fish cultural procedures.

In India, the first attempt in this direction was made as early as in 1937 (Khan, 1938) when Hamid Khan tried to induce spawning in the major carp *Cirrhina mrigala* by injection of mammalian pituitary gland, but the attempt was unsuccessful. No further attempts were made till 1955 when Chaudhuri (unpublished-*a*) succeeded in inducing spawning of the carp minnow *Esomus danricus* by intraperitoneal injection of *Catla* pituitary gland and Ramaswamy and Sundararaj (1956 and 1957 *a*) reported successful breeding of the cat-fishes *Heteropneustes fossilis* and *Clarias batrachus* by hormone injection. In 1956, success was also attained in inducing breeding of the riverine cat-fish *Pseudeutropius atherinoides* by injection of pituitary hormone from the carp *Cirrhina reba* (Chaudhuri, unpublished-*b*).

Though the study of the effect of fish pituitary glands on the spawning in Indian carps was started at the Central Inland Fisheries Research Sub-station at Cuttack by the author in 1955, it was only in 1957 that the Indian major and medium-sized carps could be successfully induced to spawn by hormone treatment (Chaudhuri and Alikunhi, 1957). The present paper is a summary of the experiments conducted by the author on induced breeding of Indian carps by injection of fish pituitary hormone. Although a number of experiments were unsuccessful, yet the details are presented in this paper as they are useful in understanding the factors which are to be avoided or overcome in such type of work in future. These experiments have been

helpful in evovling suitable techniques for successful breeding experiments as has been observed by the author in subsequent years.

Experimental Procedure and Results

The methods and procedure followed in the preliminary experiments conducted in 1955 were much different and varied than those developed during 1957 fish breeding season. The experimental procedure has therefore been described separately for the two seasons in the following paragraphs.

(A) *Experiments Conducted in* 1955

Preliminary experiments on the effect of pituitary gland hormone on the reproduction of Indian carps were initiated in the year 1955. No attempt was made to segregate the breeders early and feed them with artificial food for the proper development of the gonads. Glands were mostly collected from the Cauvery carps *Cirrhina cirrhosa* and *Labeo fimbriatus* caught from the Mettur Reservoir. Very few fishes with ripe gonads were available as donors. Pituitary glands, after removal, were washed in acetone which acted as a dehydrating and defatting agent. The glands were preserved in acetone at low temperature for two days and then taken out of acetone, put on a filter-paper and allowed to dry at room temperature for one hour. The dried glands were next transferred to sterile vials and kept inside a refrigerator until needed. A collection of acetone-dried pituitary glands of the common carp, *Cyprinus carpio*, prepared by the author during his stay in United States of America, were also used in the breeding experiments.

Just before injection, the acetone-dried glands were taken out, weighed and then the required quantity was homogenized in a tissue homogenizer with a little distilled water. The macerated gland suspension was then diluted depending on the quantity to be injected.

The injections were administered intraperitoneally by means of a 2 ml. hypodermic syringe. Needle Nos. B.D. 19–22 were used for bigger fishes and No. 24 was used for small-sized fishes. Intraperitoneal injections were given through a soft region at the base of the pelvic fin.

(*a*) *Experiments with* Labeo bata.—In July 1955, mature specimens of *Labeo bata* were collected by netting Padmapukuri Pond in Killa, Cuttack. Altogether four females and one male weighing 170–220 gm. were obtained. The sexes were segregated and kept in separate cement cisterns for a day. On the second day, one female and the male were injected intraperitoneally with 4 mg. and 2 mg. respectively of acetone-dried pituitary glands collected from *Cyprinus carpio*. The injected breeders were then released into cement cistern ($3 \cdot 6 \times 1 \cdot 8$ meters in size). The water was filled in from a tube-well

and a depth of 30 cm. was maintained. At intervals, water was also pumped in and let out simultaneously through the outlet. The fishes became very active within 8 hours after the injection and the male was found chasing the female. Next morning no spawning was observed excepting that the abdomen of the female looked more bulging. After 12 hours, another dose of 2 mg. of common carp pituitary gland was injected to each of the pair. On the following morning, a good number of eggs were collected from the cistern. The very fact that the eggs were transparent and had swollen to the normal size of carp eggs showed that ovulation had taken place but the eggs were not fertilised. This was obvious as the male was found dead in the cistern. The experiment could not be repeated as no more male *Bata* was available.

(*b*) *Experiments with* Labeo rohita.—Only twelve mature male and two mature female *Rohu* could be collected for the breeding experiments. The males and females were segregated and kept in separate ponds. One pair of *Rohu* was injected intraperitoneally with acetone-dried common carp pituitary gland. The dose administered was 6 mg. in 3 ml. and 4 mg. in 2·5 ml. of distilled water in the female and male breeder respectively. The breeders were then released into a cistern filled with tube-well water. Twenty-four hours later, the fishes were examined. While the male was oozing more freely, there was no appreciable change in the female excepting that the abdomen was less stiff. Another injection of double the previous doses was given to the pair. No spawning took place. The breeders got badly injured by striking against the wire-net cover put over the cistern.

A second pair of *Rohu* was injected with 8 mg. and 6 mg. of *Labeo fimbriatus* pituitary glands to the female and male respectively and was released in the field at Killa in accumulated rain-water. The fishes did not respond. The level of water in the field was very low and the temperature rose to over 35° C.

(*c*) *Experiments with* Catla catla.—Only one male and three female *Catla* were obtained for the breeding experiment. The male received an intraperitoneal injection of 5 mg. of acetone-dried common carp gland homogenized in 3 ml. of distilled water. A similar dose was also given to the female and the pair was released into a cistern. The fishes did not respond even after a second injection of double the previous dose. It was later observed that the breeders were not in sufficiently advanced stage of maturity.

(B) *Experiments Conducted in* 1957

In 1957, pituitary glands were mostly collected from mature gravid carps with ripe gonads, procured from the fish market at Calcutta. Although

the usual practice is to collect pituitary glands from live or freshly killed donor fish (Ball and Bacon, 1954, *op.cit.*), it was not possible to procure fresh fish for the purpose. The glands were therefore mostly collected from fishes preserved in ice and kept in the cold storage for at least 5–7 days. The glands after removal were washed in absolute alcohol and then transferred to fresh absolute alcohol (Fontenele, 1955) in an amber-coloured glass-stoppered bottle. The bottle was kept in a desiccator inside a refrigerator. The glands thus preserved were kept in absolute alcohol until needed.

Preparation of gland suspension as well as injection techniques and dosages were varied in different experiments. Prior to injection, the required number of glands were taken out of absolute alcohol and kept on a filter-paper for a few seconds, to allow the alcohol to evaporate. The glands were then macerated with a little distilled water or mostly with 0·3% common salt solution in a tissue homogenizer (Plate II, Fig. 1). The gland suspensions were injected either intraperitoneally or intramuscularly with a 2 ml. hypodermic syringe. In case of intramuscular injections, the gland suspension was invariably centrifuged in a hand centrifuge. The clear fluid containing the hormone was decanted off in a small beaker and then taken in a syringe. Intramuscular injections were usually given on the caudal peduncle (Plate II, Fig. 2) and when more than two injections were needed, the injections were also administered on the humeral region and the back muscles.

The breeding experiments were conducted at Angul situated at a distance of 128 kilometer from Cuttack. Carp breeders, netted out from various ponds, were stocked in two selected ponds and were fed regularly with artificial food. The breeders were then segregated sex-wise and transferred to separate ponds at the onset of monsoon. The experiments were started from the second week of July 1957 when regular monsoon commenced. A number of deep bag-like hand nets of assorted sizes, made of fry collection netting and stitched to bamboo or cane frame with handle, were used for carrying and handling the breeders during injection. For injection, breeders were carried from the ponds in bag hand net and placed on field table over a cushion made up of wet net pieces (Plate II, Fig. 3). Intramuscular injections were given through the meshes of the hand nets at the region of the caudal peduncle or sometimes in the humeral region. The needle was inserted under a scale, first parallel to the body of the fish and then the muscle was pierced at an angle. Immediately after the injection was given the breeders were usually released inside a *hapa* made up of close-meshed net pieces with a cover and fixed in ponds (Plate II, Fig. 4) or in accumulated rain-water in the field, inside fry carriers (1·83 × 0·76 × 0·61 m.), in glass aquarium or sometimes directly into small shallow ponds. In majority of the experi-

ments a pair of fishes was kept as control which received an equal quantity of distilled water or 0·3% salt solution according to the medium in which the gland suspension was made.

(*a*) *Experiments with* Cirrhina reba.—Ripe specimens of *Cirrhina reba* weighing from 125–270 gm. were collected from the breeders' ponds and also from other ponds. Both intraperitoneal and intramuscular injections were administered. Very low dose of pituitary gland extracts was given at the beginning. The first pair of *Reba* spawned on July 10, 1957, inside a fry carrier after receiving one intramuscular injection of 0·08 parts of a *Catla* pituitary gland. The spawning occurred in old pond-water at about six hours after the injection. The development of eggs proceeded normally. The eggs hatched out and the hatchlings were reared up to fingerling stage. This was the first instance when an Indian carp could be successfully induced to breed in confined water by treatment of pituitary gland hormone. *Reba* spawned on four more occasions with *Catla* as well as *Rohu* pituitary extracts. *Reba* also spawned once with intraperitoneal injection but it took a higher dose of two successive injections at an interval of 8 hours (Table I).

In experiments (1) and (2) females were kept separately in three-litre jars. Injections were given every six hours, intramuscularly in experiment (1) and intraperitoneally in experiment (2). A higher dose was given to the female in the second experiment. Both the females released thousands of eggs after the second injection. In case of experiment (1) the eggs were released four hours after the second injection whereas the female injected intraperitoneally took a longer time. In experiments (3) and (4), although the fishes did not spawn, the females were oozing. Artificial insemination was tried but did not succeed. Experiments (5) and (6) were carried out in shallow (28 cm.) ditches in the field, filled with accumulated rain-water. The temperature of water rose up to 38° C. The fishes did not respond. In experiment (7) the pair received only one intramuscular injection and was released inside a fry carrier filled with pond-water. A few buckets of rain-water was also added. About seven hours after the first injection, when attempts were being made to capture the breeders for a second injection, it was observed that the fishes had already spawned. The eggs were still in the early segmentation stages. The percentage of hatching was not very high probably due to the fact that the eggs were disturbed at early stages, while trying to capture the breeders.

Injected breeders in experiments (8) and (9) did not respond. The temperature of pond-water was very high, ranging from 33–36° C. The fishes were observed to be agitated. One fish from the control experiment

TABLE I

Effect of pituitary gland injection on the spawning of Cirrhina reba

Date	Expt. No.	Donor species	Mode of injection	Serial No. of injection	Sex of recipient species	Quantity of gland injected	Vol. of gland suspension injected in ml.	Injected breeders released in	Result	Remark
1957—										
July 10 ..	1	*Catla*	I_m	1st	Female	0·02	0·2	In 3-litre jar	−	..
				2nd	do.	0·02	0·2	do.	+	Unfertilised eggs released
do. ..	2	do.	I_p	1st	Female	0·06	0·5	do.	−	..
				2nd	do.	0·06	0·5	do.	+	Unfertilised eggs released
do. ..	3	do.	I_p	1st	Female	0·06	0·5	*Hapa* fixed in	−	..
					Male	0·04	0·3	pond 4		
				2nd	Female	0·07	0·5	do.	−	..
					Male	0·04	0·3	do.	−	..
do. ..	4	do.	I_p	1st	Female	0·06	0·5	do.	−	..
					Male	0·01	0·1			
				2nd	Female	0·07	0·5	do.	−	..
					Male	0·04	0·3			
do ..	5	do.	I_m	1st	Female	0·06	0·2	Shallow ditch in	−	..
					Male	0·03	0·1	the field		
do. ..	6	do.	I_m	1st	Female	0·06	0·2	do.	−	..
					Male	0·03	0·1			
do. ..	7	do.	I_m	1st	Female	0·08	0·3	Fry carrier in pond-	+++	..
					Male	0·06	0·2	water		Successful spawning

do.	30	..	8	*Rohu*	I_p	1st	Female Male	0·6 0·4	0·6 0·4	*Hapa* in pond 8	–	Temperature high
do.	31	..				2nd	Female Male	0·6 0·4	0·6 0·4	do.	–	..
do.	30	..	9	do.	I_m	1st	Female Male	0·4 0·3	0·4 0·3	do.	–	Temperature high
do.	31	..				2nd	Female Male	0·4 0·3	0·4 0·3	do.	–	..
August	13	..	10	do.	I_m	1st	Female Male	0·3 0·2	0·3 0·2	Glass aquarium in pond-water	++	Fertilised eggs released
do.	21	..	11	do.	I_m	1st	Female Male	0·3 0·2	0·3 0·2	do.	+++	Successful spawning; eggs hatched out
do.	21	..	12	do.	I_m	1st	Male	0·2	0·2	*Hapa* in accumulated rain-water	+++	do.
do.	29	..	13	do.	I_p	1st	Female Male	0·3 0·2	0·6 0·4	*Hapa* in pond 8	–	..
do.	30	..		do.	I_p	2nd	Female Male	0·5 0·3	0·6 0·4	do.	+++	Very few eggs hatched out

–, No spawning; +, Ovulation, but eggs unfertilised; ++, Fertilised eggs, stopped development, no hatching; +++ Successful spawning, eggs hatched out; I_m, Intramuscular injection; I_p, Intraperitoneal injection;

died. Experiment (10) was conducted in a glass aquarium. As the temperature of water was high, ice and ice-cold water was added occasionally. The temperature was lowered up to 27·6° C. The pair had spawned in the early morning hours. At about 5·15 hours yolk-invasion in developing eggs was half completed. Gradually water temperature started increasing and the oxygen content of the bottom layer, where more than 60,000 eggs congregated, was found to be nil. There was no further development and soon all the eggs were observed to be dead.

In experiments (11) and (12) the hormone-treated fishes spawned successfully both in the aquarium in pond-water and also in the *hapa* fixed in the field in accumulated rain-water. Total number of eggs laid in the aquarium was approximately 40,000, the percentage of developing eggs being 68%. Only a few thousand eggs could be collected from the *hapa*, as a large number seemed to have escaped through the bigger meshes of the *hapa* cloth. Heavy spawning also took place in experiment (13). The development of eggs proceeded normally in the early morning hours. But majority of eggs stopped further development and turned opaque as the weather changed suddenly and temperature of water rose to 36·5° C. Very few eggs hatched out.

(*b*) *Experiment with* Puntius sarana.—*Puntius sarana* bred first in the early hours of July 13, 1957, inside a fry carrier filled with stagnant pond-water, after receiving two doses of *Catla* pituitary gland. The eggs hatched out successfully. The hatchlings and young fry were reared in the Laboratory and the advanced fry were stocked into Nursery ponds. Another pair injected with a higher dose of *Rohu* pituitary gland bred after one injection. Only two experiments were carried out with *Sarana* and both of those were successful (Table II).

(*c*) *Experiments with* Labeo bata.—One pair of *Labeo bata* was injected intramuscularly with *Catla* pituitary glands on the evening of 10th July, and released inside a fry carrier filled with muddy water from the field. The male and the female received 0·06 and 0·08 parts of the gland respectively. The male was found dead on the following morning but thousands of fully swollen unfertilised eggs were obtained from the fry carrier. Further experiments with *Bata* could not be conducted as no male specimen could be collected inspite of all efforts. On two occasions *Bata* females were injected and released with males of *Mrigal* and *Reba* but without any success.

(*d*) *Experiments with* Labeo rohita.—Hormone treatment on *Rohu* was started on July 16, 1957. In all the experiments only the *Rohu* pituitary glands processed in absolute alcohol were used and the injections were

TABLE II

Effect of pituitary gland injection on the spawning of Puntius sarana

Date	Expt. No.	Donor species	Serial No. of injection	Sex of recipient species	Wt. in gm.	Quantity of glands injected	Vol. of gland suspension in ml.	Injected breeders released in	Result	Remark
1957—										
July 12	1	*Catla*	1st	Female	200	0·02	0·2	Fry carrier in pond 8 water	−	
				Male	246	0·02	0·2			
				Male	180	0·02	0·2			
			2nd	Female	..	0·03	0·3	do	+++	Intra-muscular injection
				Male	..	0·03	0·3			
				Male	..	0·03	0·3			
August 19	2	*Rohu*	1st	Female	800	0·5	0·3	Fry carrier	+++	do
				Male	450	0·3	0·2			

− No, spawning +++, Successful spawning; Eggs hatched out.

administered intramuscularly. Gland suspensions were made either with distilled water or in majority of the cases with 0·3% salt solution (Table III).

The results of the experiments conducted with the important major carp *Rohu* have been tabulated in Table III. It was decided at the beginning to give a series of injections at an interval of six hours, starting from a very low dose and then increasing the doses in each successive injection. This method is largely practised by the Brazilian Pisciculturists (Fontenele, 1954, *op. cit.*). The first experiment could not give decisive result as the male after the third injection escaped, although the female was in an oozing condition. In experiment (2), a smaller female was used. Just prior to the third injection when the female was brought and placed on the table for injection, it released fully mature transparent eggs which were collected in a petri dish. Immediately, milt from the male which was also brought for the third injection, was mixed with the eggs. The male was also in a fully ripe stage as the milt flowed out freely on slight pressure on the abdomen. The transparent eggs started swelling within a short time and segmentation of eggs had proceeded normally. Artificial fertilisation of eggs was thus possible. Perhaps due to restricted environment and consequent oxygen depletion further development stopped.

In the third experiment although ovulation had taken place the eggs were not fertilised. Fourth experiment did not succeed and the female died

TABLE III

Effect of pituitary injection on the spawning of Labeo rohita
Donor fish: Labeo rohita

Date	Expt. No.	Serial No. of Injection	Sex of recipient species	Weight (kg.)	Quantity of glands injected	Vol. of gland suspension in ml.	Injected breeders released in	Result	Remark
1957— July 16 ..	1	1st	Female Male	1·4 1·1	0·15 0·1	0·3 0·2	*Hapa* in pond 8	−	..
		2nd	Female Male	..	0·3 0·2	0·3 0·2	do.	−	..
		3rd	Female Male	..	0·45 0·3	0·3 0·2	do.	−	..
		4th	Female Male	..	0·6 ..	0·3 ..	..	−	Male escaped at night. Female oozing
July 16 ..	2	1st	Female Male	0·45 0·68	0·1 0·1	0·2 0·2	*Hapa* in pond 8	−	..
		2nd	Female Male	..	0·2 0·2	0·2 0·2	do.	++	Artificial insemination successful
July 17 ..	3	1st	Female Male	1·6 0·9	0·6 0·4	0·3 0·2	*Hapa* in pond 8	−	..
		2nd	Female Male	..	0·8 0·4	0·4 0·2	do.	− +	Eggs released by the female

July 18 ..	4	1st	Female Male	1·7 1·4	0·5 0·3	0·4 0·25	Fry carrier in pond-water	–	..
		2nd	Female Male	.. ..	.. ..	0·4 0·2	do.	–	Only distilled water injected
July 19 ..		3rd	Female Male	..	1·0 0·5	0·4 0·2	do.	–	Female badly injured
		4th	Female Male	..	1·5 0·75	0·4 0·2	do.	–	Female died
July 20 ..	5	1st	Female Male	0·9 0·45	0·4 0·3	0·3 0·2	*Hapa* fixed in field water	+++	Heavy spawning
July 30 ..	6	1st	Female Male	1·8 1·0	1·25 0·6	0·5 0·3	*Hapa* in pond 8	–	Hot weather
		2nd	Female Male	..	1·25 0·6	0·5 0·3	do.	–	Very high temperature
July 30 ..	7	1st	Female Male	1·25 1·8	1·0 1·0	0·5 0·5	*Hapa* in pond 8	–	Hot weather
		2nd	Female Male	..	1·0 1·0	0·5 0·5	do.	–	Very high temperature
August 19 ..	8	1st	Female Male	4·8 2·0	1·0 0·6	0·5 0·3	*Hapa* fixed in field water	+++	Heavy spawning
do. ..	9	1st	Female Male	1·7 2·0	0·6 0·6	0·3 0·3	do.	+++	Moderate spawning
August 29 ..	10	1st	Female Male	2·7 1·8	0·5 0·3	0·5 0·3	*Hapa* in pond 8	–	Temperature over 32° C.
		2nd	Female Male	.. ..	0·7 0·5	0·4 0·3	do.	–	..

–, No spawning; +, Ovulation; but eggs unfertilised; ++, Fertilised eggs. stopped development, no hatching; +++, Successful spawning, eggs hatched out.

due to injuries received by striking against the fry carrier. Experiment (5), however, gave successful result. The day was cool and cloudy. About one lakh of fertilised eggs were laid. The percentage of hatching was 95%. A large number of developing eggs were preserved and a few thousands of hatchlings were reared in the Laboratory, while 60,000 fry were stocked in a Nursery pond.

In experiments (6) and (7) higher doses were tried but the treated fishes did not spawn. The weather was extremely hot and the water temperature rose over 38° C. The breeders were very uncomfortable and were frequently coming to the surface in distress. As the number of breeders especially the males were limited, further experiments were postponed till the days of hot spell was over.

The experiments (8) and (9) were tried on cool rainy days. Successful spawning occurred in both the experiments. In experiment (8) approximately two lakhs eggs were laid by the female weighing 4·8 kg. and 68% of the eggs hatched out. The spawning in experiment (9) was moderate. Only 22,000 eggs were laid of which over 75% had hatched out. Majority of *Rohu* fry from both the experiments, were stocked in Nursery ponds while a good number of fry were reared in the Laboratory and utilised in several laboratory experiments.

By the time last experiment was started, weather had changed again. The breeders did not respond. The condition of gonads of the breeders was also not satisfactory.

(*e*) *Experiments with* Cirrhina mrigala.—The number of *Mrigal* breeders captured and stocked for the breeding experiments were very few. Only three mature female and five mature male specimens could be collected by repeated netting of the stocking ponds at Angul. Intramuscular injections of alcohol-processed *Catla* glands suspended in 0·3% salt solution were administered in all the experiments (Table IV).

The experiment (1) was started on July 16, 1957. The injected pair was released in a fry carrier in pond-water. At about five hours after the first injection, the female was found dead outside the fry carrier. The exact time when the female *Mrigal* jumped out was not known. The second pair, however, spawned successfully. The injections were given at an interval of 10 hours. While trying to remove the breeders, many eggs were damaged and perished. About two small bucketful of eggs were collected. Because of the fact that a large number of eggs were damaged, the percentage of hatching was poor. The developmental stages were studied. While a few

TABLE IV

Effect of pituitary injection on the spawning of Cirrhina mrigala
Donor fish: Catla catla

Date	Expt. No.	Serial No. of Injection	Sex of recipient fish	Weight (Kg.)	Quantity of glands injected	Vol. of gland suspension (in ml.)	Injected breeders released in	Result	Remark
1957—									
July 16 ..	1	1st	Female	0·68	0·25	0·5	Fry carrier in pond-water	–	Female jumped out after 1st injection and died
			Male	0·68	0·25	0·5			
do 19 ..	2	1st	Female	0·9	0·2	0·4	do.	–	..
			Male	0·68	0·15	0·3			
		2nd	Female	..	0·45	0·3	do.		
			Male		0·3	0·2	A few buckets of field water added	+++	Successful spawning

–, No spawning. +++, Successful spawning; Eggs hatched out.

thousands of fry were stocked in nursery pond, a large number were reared in the Laboratory and used in several laboratory experiments. The control pair which received similar dose of 0·3% salt solution only, did not spawn. The female died after two days.

(*f*) *Experiments with* Catla catla.—Greatest difficulty was encountered in distinguishing the sex of the *Catla* breeders. Eight adult *Catla* weighing from 4·1–5·6 kg. were previously stocked for the breeding experiment. None of the specimens yielded any milt on applying pressure on the abdomen. The details of the treatment is given in Table V.

In the first experiment *Catla*-1 and *Catla*-2 were found to ooze eggs after the 2nd injection. Thousands of fully swollen eggs were collected from the pond. Ovulation in the females took place but the eggs could not be fertilised as there were no mature males available at the time. Experiment (2) also did not succeed. The specimens were cut open and gonads were examined. The body cavity was full of fat and the gonads were in a very immature stage.

A fresh collection of *Catla* breeders was made from a village pond situated at a distance of 16 kilometers from Angul, and used for the third experiment. None of the breeders could be correctly sexed. Hoping that at least one of the lot of four *Catla* might be a mature female, two *Rohu* males were also injected and released into the pond along with the *Catla* breeders.

TABLE V

Effect of pituitary injection on the spawning of Catla catla

Date	Expt. No.	Serial No. of injection	Recipient fish	Weight (kg.)	Quantity of gland injected	Vol. of gland suspension (in ml.)	Injected breeder released in	Result	Remark
1957—									
July 22 ..	1	1st	*Catla* – 1	5·6	1·5	0·5			
			C– 2	5·4	1·5	0·5	Nursery pond No. 6	–	Unsexed
			C– 3	4·5	1·5	0·5			
			C– 4	4·1	1·5	0·5			
do. 23 ..		2nd	*Catla* – 1	..	2·25	0·5			Thousands of swollen unfertilised eggs; No male
			C– 2	..	2·25	0·5	do.	+	
			C– 3	..	2·25	0·5			
			C– 4	..	2·25	0·5			
do. 22 ..	2	1st	*C*– 5	5·4	1·25	0·5			
			C– 6	4·8	1·25	0·5	Nursery pond No. 5	–	All with immature gonads
			C– 7	4·5	1·25	0·5			
			C– 8	4·1	1·25	0·5			
August 19 ..	3	1st	*C*– 9	4·5	1·6	0·4			
			C–10	4·3	1·6	0·4			
			C–11	3·4	1·2	0·3	Breeding pond	–	..
			C–12	2·7	1·2	0·3			
			Rohu Male– 1	4·5	1·2	0·3			
			Rohu Male– 2	3·6	1·2	0·3			
		2nd	*C*– 9	..	1·2	0·4			
			C–10	..	1·2	0·4			
			C–11	..	1·0	0·3			All *Catla* with immature gonads
			C–12	..	1·0	0·3	do.	–	
			Rohu Male– 1	..	1·0	0·3			
			Rohu Male– 2	..	..	..			

–, No spawning. +, Ovulation; Eggs unfertilised.

No spawning took place. *Catla* breeders were then cut open and gonads examined. As in the case of previous *Catla* specimens, the gonads in these fishes too were immature and body cavities full of fat. Further experiments with *Catla* could not be continued because of the non-availability of ripe breeders.

(*g*) *Experiments with* Labeo calbasu.—Experiments with *Calbasu* could not be carried out successfully due to scarcity of ripe specimens of the species. One pair was injected on July 18, 1957, with *Rohu* pituitary glands processed in absolute alcohol. Two injections at an interval of 10 hours were given to the pair. The female weighing 1·5 kg. received 0·5 and 1·0 gland while

the male weighing 0·9 kg. received 0·3 and 0·5 parts of glands respectively. The breeders were introduced in a fry carrier in pond-water. The female in an oozing condition was found dead four hours after the second injection. No control was kept for the experiment. Another pair was caught and injected but both the fishes died as they were badly gilled at the time of netting. No other specimens could be obtained for further experiments.

(C) Hatching Techniques

(*a*) *Eggs.*—Fertilised eggs of the carps, excepting those of *Puntius sarana*, obtained from the experiments described above, swell to a great extent leaving a spacious perivitelline space. The eggs are demersal and non-adhesive. *Puntius sarana* eggs on the other hand are much smaller and with very little perivitelline space. The eggs are demersal, sticky and accumulate lot of dirt on the surface. The size of eggs in the same species of carps from different breeders vary a good deal. A comparative size of the eggs of different Indian carps obtained from the above experiments are given below.

	Species	Size of fully swollen eggs (average diameter) (mm.)
1.	*Cirrhina reba* ..	3·1–4·2
2.	*Labeo bata* (unfertilised)	3·3
3.	*Cirrhina mrigala* ..	5·0
4.	*Labeo rohita* ..	4·5–4·8
5.	*Catla catla* (unfertilised)	4·6
6.	*Puntius sarana* ..	1·2–1·3

In majority of cases of successful spawning, the eggs were not collected from the breeding *hapa* or fry carrier immediately after spawning. The breeders were also not disturbed. Only a sample of eggs were collected and taken to the Laboratory for studying the developmental stages. Eggs were collected only when the embryo was formed and started twitching movement. At this stage the eggs get properly water-hardened and do not break easily. All attempts made to remove eggs at their early stages of development gave unsatisfactory results. The breeders were removed only when the collection of eggs was over. The eggs were measured in

beakers and samples were counted for finding out the total number of eggs laid. The percentage of good developing eggs was also determined. In some cases, especially with *Rohu*, the percentage of hatching was very high reaching a maximum of 95%.

The eggs after removal from the breeding chamber were distributed in trays in the Laboratory while the majority were transferred to hatching *hapa* fixed in the pond. The hatching *hapa* used were made of thin markin cloth having a size of 1·2 × 0·9 × 0·6 m. A piece of small-meshed fry net was fitted on the top of the hatching *hapa* at a depth of 20–25 cm. below the water-surface. The developing eggs were released on the upper small-meshed net piece. Within a few hours the embryos hatched out and the hatchlings escaped through the meshes of the net piece to the hatching *hapa*. The dead eggs and the egg cases were left behind in the net piece which was removed after the hatching was over. The incubation period was observed to be 15–20 hours at a temperature ranging between 24° and 31° C.

(*b*) *Hatchlings*.—In the field, hatchlings were left in the hatching *hapa* for three days after hatching. By that time yolk was almost absorbed and fry started feeding. At the end of the third day or early fourth day the fry were measured and stocked into nursery ponds.

In the Laboratory, a large number of hatchlings of *Rohu*, *Mrigal*, *Reba* and *Sarana* were reared. The hatchlings and fry were required for conducting several laboratory experiments.

A comparative size of hatchlings, just after hatching and also at the time when the yolk is absorbed, is given below.

	Size of hatchlings just after hatching (mm.)	Size of hatchlings when the yolk is just absorbed (mm.)
1. *Cirrhina reba* ..	3·0–3·1	5·4–5·5
2. *Puntius sarana* ..	3·1–3·2	5·5–5·6
3. *Labeo rohita* ..	4·4–4·5	6·4–6·5
4. *Cirrhina mrigala* ..	4·7–4·8	6·5–6·6

Fry of the various species of carp bred by hormone treatment were reared in nursery ponds and also in the laboratory jars and aquaria. Over

95% of the fry survived in the Laboratory and growth was quite normal. Survival of fry in the nursery pond was also satisfactory. On one occasion, 60,000 *Rohu* fry were stocked into a small nursery pond. Over 25,000 early fingerlings were removed after twenty days. Several thousands of *Rohu* fingerlings were distributed to the public by the Orissa Fisheries Department and the remaining ones were stocked into stocking ponds. On another occasion, 1,18,000 *Rohu* fry were stocked into two nursery ponds. As all the well-prepared nursery ponds were already stocked with fry received from natural waters, there was no other alternative but to stock these valuable pure stock of fry in those two unprepared ponds. Plankton contents in both the ponds were very poor. Consequently the survival of fry was low. Survival and growth of *Mrigal* and *Sarana* fry in ponds were fairly satisfactory.

The productivity of Angul ponds in general is low and the rate of growth of fishes is poor. But surprisingly enough, the growth of *Rohu* fingerlings obtained by artificial breeding was remarkable. Eight months old *Rohu* fingerlings had grown to 30 cm. in size and weighed approximately 0·45 kg. each.

(*E*) *Physico-Chemical Condition of Water during Spawning*

Records of physico-chemical condition of water was kept throughout the course of the breeding experiments. The range of some of the important physico-chemical condition of water on the days of successful spawning are given below.

Temperature	..	24–31° C.
D.O.	..	2·8–9·3 p.p.m.
pH	..	8·0–8·6
Total alkalinity	..	20–98 p.p.m.
Turbidity	..	100–1000
Colour of water	..	Light brown (almost clear) to turbid

The weather condition and rainfall records were also maintained. During June–August, 1957, monsoon had failed at Angul and adjoining area and the rainfall was much below normal. A comparative statement of the rainfall during these months in 1957 compared to previous two years are given below.

Year	June (cm.)	July (cm.)	August (cm.)	Total for 3 months (cm.)
1955	20·17	11·12	51·23	82·52
1956	40·36	31·98	28·94	101·28
1957	12·11	23·18	19·43	54·72

For about a month from 21st July to 18th August 1957, there was hardly any rain and the weather was extremely hot. Most of the successful spawning took place when the temperature was comparatively low and especially on cool rainy days.

Discussion

The preliminary experiments conducted in inducing breeding of carps by hormone treatment during 1955, though did not give satisfactory results, the observations made and information gathered during those experiments, as also in other successful experiments on induced breeding conducted with some minor species of fishes during 1955 and 1956, helped in improving and developing suitable techniques which were largely responsible for the success of the experiments conducted later in 1957 on the major and medium-sized Indian carps. The results obtained during 1957 carp breeding season have clearly demonstrated that these Indian carps, which do not ordinarily breed in confined waters, could be successfully induced to breed by pituitary injection.

The failure in obtaining successful result in 1955 might be attributed at first to the poor condition of the breeders. The first requisite for successful result in any breeding experiment is to keep in readiness breeders with well-developed gonads. Secondly, the glands used for the experiments were mostly collected from adults with immature gonads. It is generally believed that the pituitary gland is most potent in fully mature gravid fishes. Menezes (1945) found out the relatively low potency of gonadotrophins in the pituitaries of immature fishes. Gerbil'skii (1940) observed low level of gonadotrophic potency in pikeperch after spawning, which continued for several months and increased when the gonads started ripening. Brazilian fish culturists therefore use glands only from ripe or ripening fish and discard glands collected from immature or regressing gonads or from spawned fishes (Menezes, 1945, *op. cit.*; Fontenele, 1955, *op. cit.*). Experiments conducted

by the author on the carp minnow. *Esomus danricus* (Chaudhuri, unpublished-*a*, *op. cit.*) in 1955 also indicated the higher efficiency of pituitary gland collected from a ripe gravid fish to that from fishes with immature gonads. In 1956 and 1957, however, pituitary glands were collected mainly from mature ripe fishes. The suitable time for collection of glands should therefore be restricted to the month just prior to the spawning season in case of seasonal breeders.

In general, the collection of glands are usually made from live or freshly killed fish (Ball and Bacon, 1954, *loc. cit.*). The Brazilians collect pituitaries within a few hours after death (Fontenele, 1955, *op. cit.*). While according to Votinov, as cited by Atz (Pickford and Atz, 1957, *op. cit.*), the Russians collect pituitary glands from freshly killed fishes or those dead not more than one or two hours. Dead fish kept at 1–3° C. for 24 hours have also proved to be satisfactory donors. The breeding experiments conducted at Angul, however, have definitely proved that it is possible to have successful results by using donor fishes which had been dead and preserved in ice for at least 5–7 days.

Creaser and Gorbman (1939) made a review on the species specificity of vertebrate series and were of the opinion that there is a specificity in hormone physiology and that there is qualitative species variation existing in gonadotropic hormones. When the variation is great enough between widely separated donor and recipient species, it leads to apparent ineffectiveness of the hormone.

The relatively higher efficiency of fish pituitary extracts on fishes over those of mammalian pituitary hormones, sex hormones and various sex steroids has been indicated in the elaborate review of the available literature made by Atz (Pickford and Atz, 1957, *op. cit.*) and also by Chaudhuri (1956). Watanabe *et al.* (1950) made a comparative study of the effects of the hypophyseal hormones of salmon, cat-fish, snake and lizard on the loach and found that the pituitary hormone of salmon was more effective than that of other species. Chaudhuri (1956, *op. cit.*) obtained best result by using the glands from the donor fish belonging to the same species as the recipient fish, although glands from other species, were also effective. But mammalian sex hormones did not have the desired effect on the fish. Although there are reports of some positive results on fishes treated with amphibian pituitary glands and mammalian chorionic gonadotrophin (Fugita *et al.*, 1948, *op. cit.*; Ramaswamy and Sundararaj, 1957 *b*, 1957 *c*) but so far the hormones of mammalian origin have not been found to be as effective as the fish pituitary

hormone or are the mammalian hormones used by any fish culturists as a regular part of fish cultural operations.

In the present series of experiments it was decided to use only fish pituitary glands, preferably from the same or closely related species, for injection. *Catla* pituitary gland was found to induce successful spawning in *Cirrhina mrigala*, *Cirrhina reba* and *Puntius sarana*. *Rohu* pituitary glands were successfully used not only in *Labeo rohita* but also in *Cirrhina reba* and *Puntius sarana*. *Rohu* glands also induced ovulation in *Catla catla* and *Labeo bata*. Although only the carp glands were used for inducing spawning in carps in 1957, it was also possible in 1956 to breed the riverine cat-fish *Pseudeutropius atherinoides* by injecting carp (*Cirrhina reba*) pituitary gland (Chaudhuri, unpublished-*b*, *op. cit.*).

For the preservation of pituitary glands for future piscicultural use, two methods have been widely in vogue. Acetone-dried pituitary glands are largely used in U.S.S.R. and U.S.A., while the Brazilians claim better success with absolute alcohol preserved material. The author tried both the methods of preservations and found the latter method more suitable for India where refrigeration facilities are not very common. In 1955, fishes were treated with acetone-dried glands, while glands preserved in absolute alcohol were alone used in all the experiments in 1957.

For preparation of gland suspension for injection, different workers have used different solutions. Physiologists prefer the use of physiological solution, that is, a solution which is isotonic with the blood of the recipient animal. For inducing spawning in fishes, different strength of common salt solution (Ihering, 1937; Palmer *et al.*, 1954), Holtfreters solution (Ramaswamy and Sundararaj, 1957 *b*, *op. cit.*), etc., have been used in place of distilled water although successful results have been obtained by using distilled water only.

The method of injection of hypophysis extracts has been used differently by different workers. The most popular and effective method of injection is the intramuscular one which is largely followed by the Brazilian fish culturists. The intracranial injection of pituitary extracts was the favourite method in U.S.S.R. for several years but they switched over to the simpler technique of intramuscular injection finding the method more convenient. Intraperitoneal injection is more popular with the majority of the workers in Japan and U.S.A. (Kawajiri *et al.*, 1948, *op. cit.*; Migita *et al.*, 1952, *op. cit.*; Hasler *et al.*, 1940). Ball and Bacon (1954, *op. cit.*) tried intramuscular injection on minnows and almost without exception found unsatisfactory results and nearly all the fishes so treated died. They subsequently adopted

the method of intraperitoneal injection in their work. The probable reason for reaction in treated fishes might be attributed to the use of unfiltered gland suspension. In administering intraperitoneal injection in fully ripe fishes, there is every risk of damaging the internal organs especially the distended gonads. Besides, as the gland suspensions in intraperitoneal injection are usually not filtered, repeated injections might give harmful reaction as observed by Pickford, cited by Atz (Pickford and Atz, 1957, *op. cit.*) that "Repeated intraperitoneal injection of an unfiltered suspension of acetone powder should be avoided since the denatured protein is apparently not assimilated and accumulates in the body cavity leading to adhesions."

In the present series of experiments, results were obtained by both intramuscular as well as intraperitoneal injections. But the former method has been found to be more effective and better suited for the purpose and were used in majority of the experiments. For successful results an intraperitoneal injection required much higher dose of the gland material than when the fishes were injected intramuscularly.

Determination of proper dosage of gonadotrophin for inducing successful spawning in fishes, is of utmost importance. Very few workers have so far been able to standardise the actual dose of the pituitary gland hormone to be administered in particular species. Chemical standardisation of fish gonadotrophins depends on a variety of factors of which the size and stage of sexual maturity of the recipient fish is the most important one. Besides, the potency of the glands also vary according to the time of collection of glands, size and stage of sexual development and species of the donor fish. According to Atz (Pickford and Atz, 1957, *op. cit.*) the Russian workers are the only ones who have developed a method of biological assay of the fish gonadotrophins. The Brazilians though using the method in pisciculture with success from the early thirties have not yet been able to standardise the doses. They use individual whole pituitary gland. Attempts are still being made to standardise the methods although several *Fish units* have been provisionally suggested by a number of workers. Fontenele (1955, *op. cit.*) while describing the method of hormone treatment on common *curimata* reported the use of the amount of hormones obtained from a whole pituitary gland from a *curimata* of well-developed gonads as the conventional unit, in the absence of more accurate unit of measurement.

In the experiments described in the preceding pages both acetone-dried gland weighing in mg. and whole individual glands were used. The dose of injection required to induce successful spawning depended on the size and stage of maturity of the breeders. While a female *Rohu* of 0·9 kg.

needed 0·4 parts of a gland for successful spawning, it took one full gland and 0·6 parts of gland for *Rohu* females weighing 4·8 kg. and 1·7 kg. respectively. But in few other cases similar dose given to similar weight of fishes did not give any result. By experience only a fish breeder can determine the proper dose needed to induce spawning in a particular fish.

During the course of the experiments the greatest difficulty encountered was due to failure to determine the exact stage of maturity of the ovaries of female breeders by external examination. Contradictory results were therefore obtained by giving same dose to the breeders of similar weights but differing in the stage of maturity of gonads. Females ordinarily were given slightly higher doses than males as the males were already oozing milt on slight pressure on the abdomen. Successful results were obtained in many instances within 6–8 hours after the first injection. In other cases a second injection made at an interval of 8–10 hours induced spawning, whereas in a few cases, repeated injections failed to produce any result. The usual practice in Brazilian pisciculture as summed up by Atz and Pickford (1959), is as follows. "Females generally required higher doses than the males. Small multiple injections gave better results than single large ones. In practice from four to eight intramuscular injections are given, usually at six hours intervals, until the fish show by their behaviour that they are ready to spawn. A partition separating males from females in the aquarium is then removed and spawning is allowed to take place. The total amount of pituitary extract administered may be equivalent to as little as one-half or to as much as five glands, depending on the responsiveness of the recipient." In case of Indian carps which are very active fishes, jump wildly and struggle, repeated injections do not always give successful results as the fishes injure themselves badly by repeated nettings and handling.

While treating fishes with pituitary gland extracts in the fish breeding experiments conducted by the author, no distinction was made with regard to glands collected from different sexes of the donor fish. Ball and Bacon (1954, *op. cit.*), observed that the pituitaries from male common carp were not as effective on the treated female creak chub. Ramaswamy and Sundararaj (1957 *a*, 1957 *b*, *op. cit.*) found that the male pituitary glands of *Heteropneustes fossilis* were less potent than the female pituitaries, but could not find any difference in case of *Clarias batrachus*. Palmer *et al.* (1954, *op. cit.*) injected pituitary glands of opposite sex to the males and females of Blue back Salmon but did not find any antagonistic action. According to Fontenele (1955, *op. cit.*), the results of the researches conducted in the Servico de Piscicultura, D.N.O.C.S., Brazil, have proved the non-specificity

with regard to sex of the fish pituitary hormone. So far, there are no sufficient experimental data to prove definitely whether any variation in potency of the male and female glands, really exists. Majority of fish culturists, therefore, do not make any difference between glands of either sex and use those indiscriminately.

Proper identification of the sex and stage of maturity of the breeders is absolutely essential for successful results. Attempts were made to find out some field method of identifying sexes of the Indian carps. The identifying characters observed in 1957 and during 1958 carp breeding season have been described by Chaudhuri (1959). It was also observed that many adult fishes especially *Catla* and a few *Rohu* and *Mrigal* did not develop any ripe gonads. The fishes had attained the age of maturity but the gonads were still in the early immature stage. They had accumulated lot of fat in the body cavity. From external examination these fishes could not be distinguished from ordinary females. It would be interesting to know the reasons for such abnormal condition in these fishes.

A high percentage of eggs hatched out in majority of the cases of successful spawning. The period of incubation varied from 15–20 hours depending on the prevailing water temperature. The growth of fry in nursery ponds and fingerlings in the stocking ponds were found to be normal.

While making a critical study of the results of the fish breeding experiments conducted at Angul, it was observed that successful spawning had been induced in majority of the cases when the weather condition was much cooler, on cloudy and rainy days and especially after heavy showers. Fresh rain-water gave better result. The fishes usually did not respond on hot sunny days. The temperature of water in all the cases of successful spawning varied between 24 and 31° C. The fishes did not respond when the temperature rose much higher.

From the experiments so far conducted it appears that the environmental factors during the spawning season have a great influence on the gonadotropic activities of the pituitary of fishes. Among the environmental factors, rain-water, temperature and light are stated to have considerable influence on the reproduction of fishes. While studying the factors responsible for the spawning of Indian carps in natural waters, several workers have suggested a number of factors like rain-water, flood, temperature, etc., Hora (1945, *op. cit.*) while discussing the factors influencing spawning of Indian carps stressed among other factors, heavy monsoon flood and optimum temperature for spawning as between 24 and 30° C. Khan (1945) concluded that a combination of factors like rains, floods and temperature

and chemical and physical factors responsible for spawning. He observed the temperature ranges of the spawning grounds from 24–31° C. It is well known that there are critical temperature ranges beyond which fishes fail to spawn. Chaudhuri (1956, *op. cit.*) observed that a minimum threshold of temperature was necessary for spawning in gold-fish and that freshwater accelerated the intensity of spawning. The physico-chemical factors other than temperature and flood-water do not appear to play any significant part in the spawning of fishes. Spawning occurred both in almost clear as well as turbid water and both during the day and night.

The experiments conducted in inducing breeding of Indian carps by pituitary hormone injection have yielded interesting and valuable results. If the improved techniques suggested in this paper are effectively adopted it will lead to production of quality fish seed on a commercial scale to meet the great demand of fish seeds in India for stocking all inland waters. Concerted efforts are now being directed towards this objective.

Summary

Preliminary experiments were conducted to determine the effect of pituitary gland injection in inducing spawning of Indian carps. Indian carps do not ordinarily breed in confined waters and as such there is dearth of fish seed for stocking inland waters. The results of the experiments conducted in 1955 and 1957 are summarised below:—

(A) *In* 1955

1. *Labeo bata* injected intraperitoneally with acetone-dried pituitary glands from common carp ovulated, but the eggs could not be fertilised as the only available male had died.

2. The major carps *Catla catla* and *Labeo rohita* did not respond when each received two doses of intraperitoneal injections of acetone-dried pituitary glands from common carp. The condition of breeders were not satisfactory.

(B) *In* 1957

1. On July 10, 1957, first success was met in inducing an Indian carp to breed successfully by hormone treatment.

2. Successful spawning of *Labeo rohita*, *Cirrhina mrigala*, *Cirrhina reba* and *Puntius sarana* took place by pituitary injection.

3. Partial success in *Catla catla* and *Labeo bata* was met with when the females ovulated on being treated with hormone.

4. Pituitary glands from fish of the same or closely related species were only used for injection. *Catla* glands induced spawning in *Reba*, *Sarana* and *Mrigal*, while *Rohu* glands induced successful spawning in *Rohu*, *Reba* and *Sarana* and ovulation in *Catla* and *Bata*.

5. Glands collected from ripe fishes preserved in ice for about 5–7 days gave successful results.

6. Gland suspensions were made both in distilled water and 0·3% common salt solution and used after centrifuging.

7. Both intraperitoneal as well as intramuscular injections were made with positive results. Intramuscular injection was more effective and needed a smaller dose than the intraperitoneal injection.

8. Spawning occurred in some cases 6–8 hours after the first injection, in a few cases after a second injection at an interval of 8–10 hours, while in a few other cases repeated injections did not give result.

9. No distinction between the glands from the sexes of donor fishes was made and the glands were used indiscriminately in both male and female recipient fish with positive results.

10. The doses appear to depend on the size and stage of maturity of the gonads of the breeders.

11. The minimum successful dose was 0·05 parts of *Catla* gland administered in two doses at an interval of 10 hours to a female *Sarana* weighing 200 gm. while a still lower dose of 0·04 parts of *Catla* gland induced ovulation in *Reba* weighing 165 gm.

12. The maximum successful dose which induced spawning in a female *Rohu* weighing 4·8 kg. in one injection was one full *Rohu* gland.

13. Cool rainy days were found to be conducive to successful spawning. Majority of the successful spawnings were associated with rains.

14. The results were unsatisfactory on hot sunny days when the temperature of water was very high.

15. The optimum range of temperature when all spawning took place was between 24 and 31° C.

16. The fishes bred both during daytime as well as at night.

17. Spawning took place in almost clear water as well as in turbid water.

18. In most cases of successful spawning the majority of eggs were fertilised and the hatching rate was as high as 95%.

19. The eggs developed normally and the incubation period varied between 15 and 20 hours depending on the prevailing water temperature.

20. The survival and growth of fry and fingerlings in nurseries and stocking ponds respectively were quite satisfactory.

I am deeply indebted to Dr. B. S. Bhimachar, Chief Research Officer, for his kind interest and valuable suggestions in the progress of the study, and for kindly going through the manuscript and suggesting improvements; to Shri G. N. Mitra, Director of Fisheries, Orissa, for kindly providing me with all field and laboratory facilities at Angul. My thanks are due to Shri K. H. Alikunhi, Research Officer for encouragement during the course of this work. I also wish to express my thanks to Shri G. N. Saha for supplying the data on physico-chemical conditions of water during spawning and to Shri B. M. Mishra, District Fishery Officer, Orissa, for the kind help rendered by him.

References

1. Atz, J. W. and Pickford, G. E. 1959 — The use of pituitary hormones in fish culture. *Endeavour*, **18** (71), 125–29.

2. Baldwin, F. M. and Li, Min-Hsin. 1942 — Effects of gonadotropic hormones in fish, *Xiphophorous helleri* Heckel. *Proc. Soc. Exp. Biol. Med.*, **49**, 601–04.

3. Ball, R. C. and Bacon, E. H. 1954 — Use of pituitary material in the propagation of minnows *Prog. Fish-Cult.*, **16** (3), 108–13.

4. Berkowitz, P. 1941 .. The response of fish (*Lebistes reticulatus*) to mammalian gonadotropins. *J. Exper. Zool.*, **86**, 247–53.

5. Burrows, R. E., Palmer, D. D. and Newman, H. W. 1952 — Effects of injected pituitary material upon the spawning of blue back salmon. *Prog. Fish-Cult.*, **14** (3), 113–16.

6. Cardoso, D. M. 1934 .. Relacao genito—hypofisaria e reproducao nos peixes. *Arch. Inst. Biol.* (S. Paulo), **5**, 133–36; *Biol. Abst.*, **10** (3), 600, 1936.

7. Chaudhuri, H. 1956 .. Effect of pituitary injections and other factors on reproduction of pond fishes. *Ala. Pol. Inst. Bull.*, 1956 (M.S.—Dissertation).

8. ———— *a*. .. Successful spawning of the carp minnow, *Esomus danricus* by pituitary gland injection. *Study of the Life-histroy and Bionomics* (Unpublished).

9. ———— *b*. .. Spawning induced successfully in the riverine cat-fish, *Pseudeutropius atherinoides*. *Ibid.* (Unpublished).

10. ————. 1959 .. Notes on external characters distinguishing sex of breeders of the common Indian carps. *Sci. & Cult.*, **25** (10), 258–59.

11. ——— and Alikunhi, K. H. 1957 — Observation on the spawning in Indian carps by hormone injection. *Curr. Sci.*, **26** (12), 381–82.

12. Combs, B. D. and Burrows, R. E. 1959 — Effects of injected gonadotrophins on maturation and spawning of Blueback salmon. *Prog. Fish-Cult.*, **21** (4), 165–68.

13. Creaser, C. W. and Gorbman, A. 1939 — Species specificity of the gonadotropic factors in Vertebrates. *Quart. Rev. Biol.*, **14** (3), 311–31.

14. Eversole, W. J. 1941 — The effects of pregneninolone and related steroids on sexual development of fish (*Lebistes reticulatus*). *Endocrinology*, **28**, 603–10.

15. Fontenele, O. 1955 .. Injecting pituitary (hypophyseal) hormones into fish to induce spawning. *Prog. Fish-Cult.*, **17** (2), 71–75.

16. Fujita, T., Uno, K., Yatsunagi, K. and Kubota, Z. 1946 — On artificial taking of eggs of loach by injection of pituitary hormone. *Contr. Cent. Fish. Stn. Jap.*, **44**, 254–58.

17. Gerbil'skii, N. L. 1938 .. Expedition for the study of the physiology of spawning. *Rybonoe Khoziaistvo*, **18** (10), 33–36.

18. ————. 1940 .. Seasonal changes of the gonadotropic potency of the pituitary glands in fishes. *C.R. Acad. Sci., Moscou*, **28** (6), 571–73.

19. Hasler, A. D., Meyer, R. K. and Field, H. M. 1939 — Spawning induced prematurely in trout with the aid of pituitary glands of the carp. *Endocrinology*, **25** (6), 978–83.

20. ————. 1940 .. The use of hormone for the conservation of muskellunge, *Esox masquinongy immaculatus* Garrard. *Copeia*, **1940** (1), 43–46.

21. Hoar, W. S. 1957 .. Endocrine organs. *The Physiology of Fishes*, **1** (6), Edited by M. E. Brown, Academic Press, N.Y.

22. Hora, S. L. 1945 .. Symposium on the factors influencing the spawning of carps: Analysis of factors influencing the spawning of carps. *Proc. Nat. Inst. Sci. Ind.*, **11** (3), 303–12.

23. Houssay, B. A. 1931 .. Action sexuelle de l'hypophyse sur les poissons et les reptiles. *C.R. Soc. Biol., Paris*, **106**, 377–78.

24. Ihering, R. von. 1937 .. A method for inducing fish to spawn. *Prog. Fish-Cult.*, **24**, 15–16.

25. ——— and Azevedo, P. de. 1934 — A curimata dos acudes nordestinos (*Prochilodus argenteus*). *Arch. Inst. Biol.*, S. Paulo, **5**, 143–84.

26. Johnson, M. and Riddle, O. 1939 — Tests of mammalian gonad stimulating hormones on gonads of fishes. *Proc. Soc. Exp. Biol. Med.*, **42**, 260–62.

27. Kawajiri, M., Shimadate, M., Koyama, H. and Miyajima, C. 1948 — Inducing spawning by hormones of female carp. *Contr. Cent. Fish. Stn. Japan*, 1946, 13–16; *Biol. Abst.*, **26**, 755, 1952.

28. Kawamoto, N. Y. 1950 .. The influence of sex hormones on the reproductive organs of a Sogyo *Ctenopharyngodon idellus* (C. & V.). *Jap. J. Ichthyol.*, **1**, 8–15.

29. Kawamura, T. and Motanaga, T. 1950 — On artificial ovulation in the spinous loach. *Ibid.*, **1**, 1–7.

30. Kazanski, B. N. 1939 .. The sturgeon production station Veltianka on the River Volga. *Rybnoe Khoziaistvo*, **19** (11), 21–22.

31. Khan, H. 1938 .. Ovulation in fish (Effect of administration of anterior lobe of pituitary gland). *Curr. Sci.*, 7 (5), 233–34.

32. ————. 1945 .. Symposium on the factors influencing the spawning of carps: Observations on the spawning behaviour of carp in the Punjab. *Proc. Nat. Inst. Sci. Ind.*, **11** (3), 315–20.

33. Mathews, S. A. 1939 .. The relationship between the pituitary gland and the gonads in *Fundulus*. *Biol. Bull.*, **76**, 241–50.

34. Menezes, R. S. de. 1945 Acao de hipofises de peixes doadores em diestro sobre peixes reproductores em estro. *Rev. Bras. Biol.*, **5** (4), 535–39; *Biol. Abst.*, 1946, **20**, 2093 (English summary).

35. Migita, M., Matsumoto, J., Kinoshita, H., Sasaki, A. and Ashikawa, I. 1952 Studies on the hypophyseal hormone of fishes. I. Stimulating effect upon the ovulation of trout. *Bull. Jap. Soc. Fish.*, **17** (8–9), 25–31.

36. Oordt, G. J. V. and Bretschneider, L. H. 1941 Uber den Einfluss gonadotroper Stoffe auf die Entwicklung der Hoden des aasles (*Anguilla anguilla* L.). *Wilhelm Roux Arch. Entwicklungsmach. Organ.*, **141** (1), 45–57.

37. Owen, S. E. 1936 .. The reaction of fish to sex hormones. *Endocrinology*, **20**, 214–18.

38. Palmer, D. D., Burrews, R. E., Robertson, O. H. and Newman, H. W. 1954 Further studies on the reactions of blueback salmon to injected salmon and mammalian gonadotrophins. *Prog. Fish-Cult.*, **16** (3), 99–107.

39. Pickford, G. E. and Atz., J. W. 1957 .. The physiology of the pituitary gland of fishes. *N.Y. Zool. Soc.*, New York. Pp. 613.

40. Pliszka, F. 1951 .. Effect on the Testicle of *V. vimba* of therapeutic injections of its hypophysis. *Roczn. Nauk rol.*, **58**, 385–95. (In Polish with English summary).

41. Ramaswamy, L. S. and Sundararaj, B. I. 1956 Inducing spawning in the Indian cat-fish. *Science*, **123** (3207), 1080.

42. ————. 1957 *a* .. Induced spawning in the cat-fish *Clarius*. *Naturwiss.*, **44**, 384.

43. ————. 1957 *b* .. Inducing spawning in the Indian cat-fish *Heteropneustes* with pituitary injections. *Acta Anat.*, **31**, 551–62.

44. ————. 1957 *c* .. Induced spawning in the cat-fish *Heteropneustes* with mammalian chorionic gonadotrophins. *Ibid.*, **32**, 230–34.

45. Vivien, J. H. 1939 .. Relations hypophyse-genitales chez quelque teleosteens et selaciens. *C.R. Soc. Biol., Paris*, **131**, 1222–24.

46. Watanabe, M., Yamada, A. and Matsushima, M. 1950 On the effects of the hormone of the anterior lobe of the hypophysis upon the loach. II. Salmon, cat-fish, snake lizard and pre-hormone. *Bull. Jap. Soc. Sci. Fish.*, **15** (12), 799–802.

47. Young, J. Z. and Bellerby, C. W. 1935 The response of the lamprey to injection of anterior lobe pituitary extract. *J. Exp. Biol.*, **12**, 246–53.

FIGS. 1–4. Fig. 1. Maceration of pituitary gland in a tissue homogenizer. Fig. 2. Demonstration of intramuscular injection on a dead fish. The method of insertion of the needle is shown. Fig. 3. Intramuscular injection being given to a breeder, through the meshes of the hand-net, at the caudal peduncle. Fig. 4. Breeding 'hapa' fixed in a pond.

OBSERVATIONS ON THE DISTRIBUTION AND OCCURRENCE OF DIATOMS IN THE INSHORE WATERS OF THE GULF OF MANNAR AND PALK BAY

By R. Raghu Prasad and P. V. Ramachandran Nair

(*Central Marine Fisheries Research Station*)

Introduction

From year to year qualitative and quantitative variations, as well as fluctuations of a minor nature in the regularity in appearance or disappearance of diatoms and their blooms are found in every region. As the diatoms constitute the chief components of the primary food supply of the sea, data on their occurrence, distribution pattern and fluctuations are of importance. Therefore, an attempt was made to study the nature and composition of the diatom community that occur in the plankton of Mandapam area, the abundance of species and the recurrent pattern in the annual distribution of the various species.

The results are based on regular tow-net samples collected from the inshore waters of the Gulf of Mannar during January 1950 to June 1953 and Palk Bay during May 1951 to June 1953.

The authors wish to thank Dr. S. Jones, Chief Research Officer, Central Marine Fisheries Research Station, for his comments.

General Character of the Diatom Flora

Several species of diatoms occur in the plankton of the Gulf of Mannar and Palk Bay, but out of these only about fifteen are well represented, most of which have been noticed to exhibit some kind of periodicities. The less abundant species do not show any clear seasonal fluctuations, but there are instances when some of these appear in appreciable numbers.

The principal constituents of the diatom population that occur in plankton, as can be expected, are the pelagic species of neritic and oceanic provinces. The littoral species are comparatively few.

Based on the available information regarding the bio-geographical types, species usually found in the plankton of this area may be grouped as follows:

Neritic—

Arctic	.. *Fragilaria oceanica*
	Nitzschia seriata
North Temperate	.. *Chætoceros compressus*
	Leptocylindrus danicus
	Rhizosolenia stolterfothii
	R. imbricata
	Thalassionema nitzschioides
South Temperate	.. *Asterionella japonica*
	Bacteriastrum hyalinum
	Biddulphia mobiliensis
	Chætoceros affinis
	C. didymus
	C. lascinosus
	C. lorenzianus
	Ditylum brightwellii
	Eucampia zoodiacus
	Guinardia sp.
	Hemiaulus sinensis
Tropical	.. *Bacteriastrum varians*
	Bellarochea malleus
	Chætoceros diversus
	C. indicus
	Coscinodiscus gigas
	Leptocylindrus minimus
	Stephanopyxis palmeriana
	Thalassiosira coromandeliana
	Triceratium favus

Oceanic—

Temperate	.. *Bacteriastrum delicatulum*
	Chætoceros peruvianus
	Rhizosolenia alata
	R. styliformis
	Thalassiothrix frauenfeldii

Tropical .. *Biddulphia sinensis*
Chætoceros coarctatus
Hemidiscus hardmannianus
Planktoniella sol
Rhizosolenia calcar avis
R. castracanei
R. hebetata
R. robusta

Littoral—
.. *Bacillaria paradoxa*
Biddulphia pulchella
Climacosphenia elongata
Isthmia enervis
Melosira sulcata
Nitzschia closterium
N. longissima
Pleurosigma spp.
Rhabdonema spp.

It will be seen from the classification given above, that Arctic neritic species are represented only by two species, whereas there are no Arctic oceanic species in the local flora. There are sixteen temperate neritic, nine tropical neritic, five temperate oceanic and eight tropical oceanic species. Nine species are littoral. Two other species which occur commonly, *viz.*, *Schrœderella delicatula* and *Chætoceros denticulatum* are unclassified.

Most of the species occurring at both the areas and constituting the bulk in many months of the year are the so-called temperate forms. *Chætoceros* spp., *Rhizosolenia alata*, *R. imbricata*, *Thalassionema nitzschioides*, *Thalassiothrix frauenfeldii*, *Bacteriastrum hyalinum*, *Biddulphia sinensis* were the predominant ones occurring both in the Gulf of Mannar and Palk Bay. Besides, *Thalassiosira coromandeliana*, *Guinardia* sp., *R. styliformis*, *R. calcar avis*, *R. castracanei*, *Hemiaulus sinensis*, *Bacteriastrum varians*, *Chætoceros denticulatum*, *Climacosphenia elongata* and *Asterionella japonica* were found in great numbers only in Palk Bay, most of which are either south temperate or tropical neritic forms. In the Gulf of Mannar, on the other hand, species such as *Chætoceros coarctatus*, *Ditylum brightwellii*, *Biddulphia sinensis* and *Hemidiscus hardmannianus*, which are mostly tropical oceanic forms, were more common. Prasad (1954) observed blooms of single species of *Rhizosolenia*, *R. imbricata* in February 1951 and *R. alata* during March

1950 in the Gulf of Mannar, whereas during the summer as well as the August to September maxima more than one genus and several species were noticed flowering. He also observed that there are variations in the species composition of the diatom maxima taking place at different months of the year.

Seasonal occurrence and abundance of the more common species

Asterionella japonica Cleve (Fig. 1).—This species was often an important constituent in Palk Bay from February to April and from June to November, with the maximum abundance in August when they occurred in blooms. In the Gulf of Mannar its distribution was rather sparse except during the summer. Thus, in May 1950 it appeared in large numbers but was totally absent during the same period in the next two successive years and again reappeared, though in less number, in 1953. The largest catch was made in August 1951 from Palk Bay when a weekly average of 162,000 cells/c.c. of the standardised sample were obtained, whereas the largest

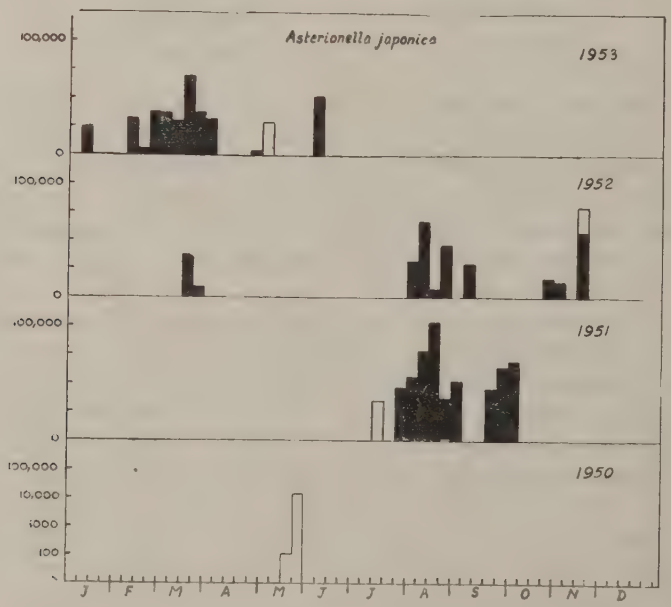


FIG. 1

FIGS. 1–15. Show the distribution and abundance of 15 common species of diatoms in the Gulf of Mannar (open bars) and Palk Bay (black bars) based on weekly tow-net samples. In all these figures the numbers on the ordinates represent the number of diatom cells per c.c. of the standardised sample.

obtained from the Gulf of Mannar was only 19,000 cells/c.c. in November 1952. There seems to be a regularity in their occurrence in Palk Bay during successive years, whereas such is not the case in the Gulf of Mannar. Allen (1945) states: "Apparently, it is one of those erratic organisms with extremes of abundance which are not seasonal (or even annual) in occurrence but are based on more or less fortuitously favourable combinations of the required conditions (external and internal)."

Bacteriastrum hyalinum Lauder (Fig. 2) occurred at both places during the summer blooms as well as the one during the latter part of the year. It was most abundant in Palk Bay from April to June and September to November and totally absent during the rest of the year. Excepting for a casual occurrence in July in one year it was found only in the major phytoplankton peaks of the Gulf with an interlude of one or two years.

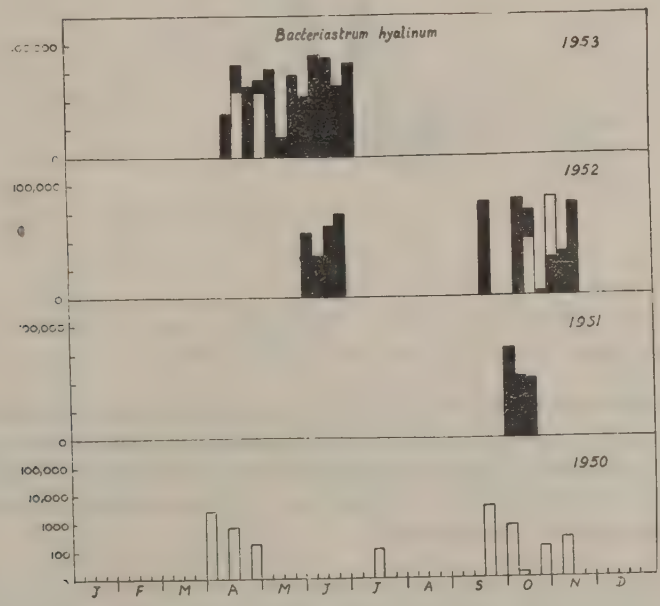


FIG. 2

Bacteriastrum varians Lauder (Fig. 3) is a more warm water species than *B. hyalinum*. In the Gulf of Mannar it was one of the constituents of the phytoplankton bulk of April to May 1950 and August 1951. In Palk Bay from May to October it occurred at intervals and was abundant,

Periods of swarms for both stations were May to June. A regular periodicity in their abundance during the summer months was observed in Palk Bay.

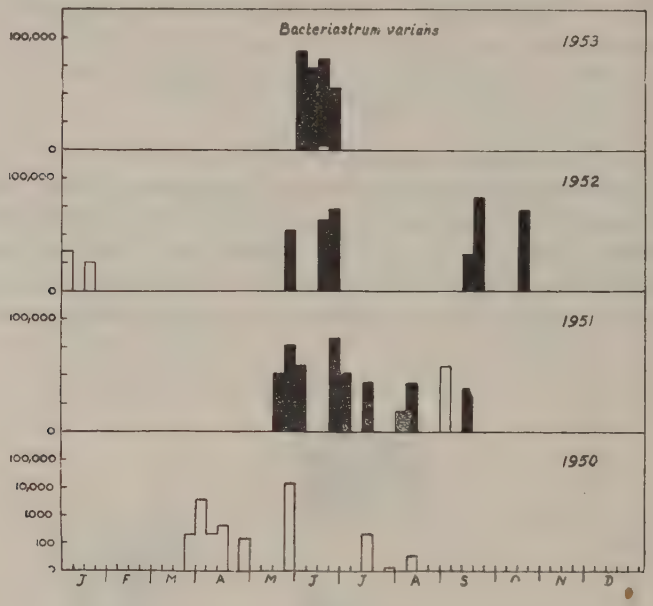


FIG. 3

The genus *Bacteriastrum* can be considered as one of the four dominant genera that makes up the diatom bulk of this area.

Biddulphia sinensis Greville (Fig. 4) is considered as a tropical neritic species which has invaded the temperate waters of Europe where it has become a permanent member of the plankton. According to Lebour (1930) this species has been used as an indicator of currents and for determination of the rate of flow of currents.

Being a tropical species *Biddulphia sinensis* is more common than the other member of this planktonic genus which occurs in this area, *viz.*, *B. mobiliensis*. In the Gulf of Mannar it occurred almost throughout the year in fairly good numbers with a maximum during the summer. In Palk Bay it appeared at irregular intervals almost throughout the year and had a maximum sometime during June to July. During the second diatom peak also it may occur in small numbers. The highest average number of cells

from the Gulf of Mannar was 38,000, whereas from Palk Bay it never exceeded 1,200.

Sproston (1949) noted that it is a conspicuous autumn dominant and may persist into the winter, in the Chu-San region. However, in the present instance, it was found to be dominant in summer.

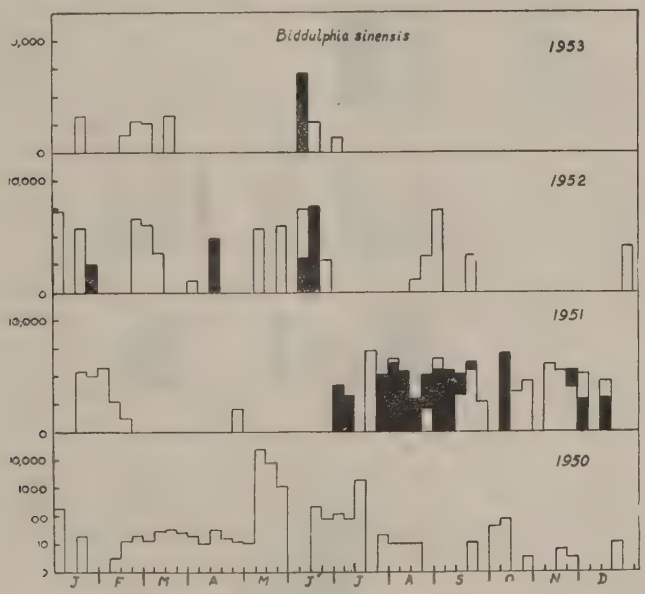


FIG. 4

Biddulphia mobiliensis also occurred in the plankton commonly. According to Gough (1907) it belongs to the winter plankton at Plymouth. But in Gulf of Mannar it was found in February, March, May and August to October. The highest number recorded was 12,000 in July and November 1951. In Palk Bay *B. mobiliensis* was almost absent excepting for a stray occurrence of few cells in June.

Chætoceros indicus Subrahmanyan (Fig. 5) was described for the first time from the plankton of the Madras coast (Subrahmanyan, 1946) and details of its abundance in any particular area or its geographical distribution beyond our waters are not available at present. In view of its abundant occurrence in the inshore plankton of both the areas it has been considered as a tropical neritic form.

This species was one of the major constituents of the diatom maxima of both the areas, but comparatively it was more abundant in Palk Bay where it occurred from May to December. In the Gulf of Mannar it occurred in small numbers intermittently from April to December. May

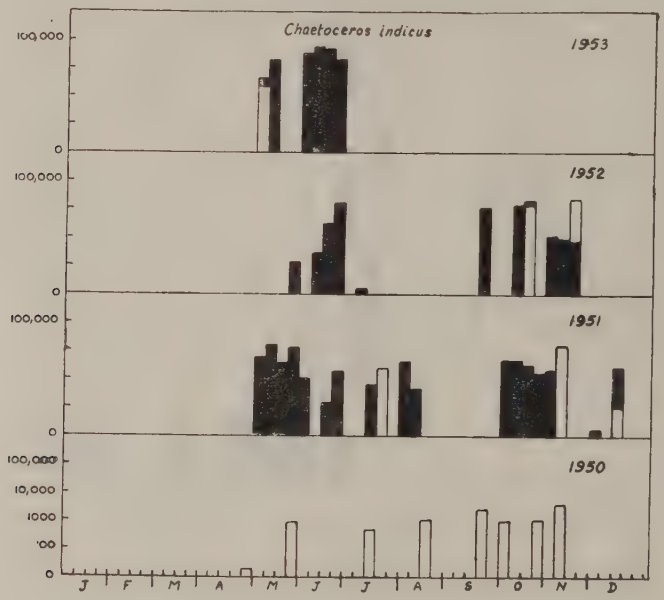


FIG. 5

and September to November were the two major peaks and during the period of observation they showed a regular periodicity in occurrence. The two major diatom blooms are well reflected in the occurrence of *C. indicus*. The largest catch from Palk Bay was 75,000 cells and from the Gulf of Mannar it was only 37,000 cells/c.c.

Chætoceros lascinosus Schütt (Fig. 6), a prominent species in Palk Bay, occurred regularly during the two major peaks and almost totally absent at other times of the year. In the Gulf of Mannar it occurred intermittently during May to December without showing any regular sequence or periodicity. The largest catch of 224,000 cells was from Palk Bay in June 1953, whereas from the Gulf of Mannar it was only 22,000 cells.

Chætoceros lorenzianus Grunow (Fig. 7) occurred in the Gulf of Mannar almost throughout the year forming a major part of the diatom population.

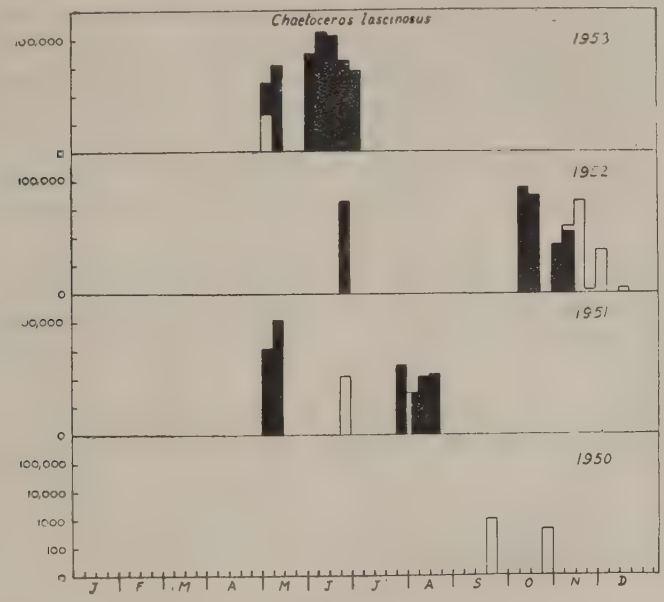

Chaetoceros lascinosus
1953
1952
1951
1950
100,000
10,000
1000
100
0
J F M A M J J A S O N D

FIG. 6

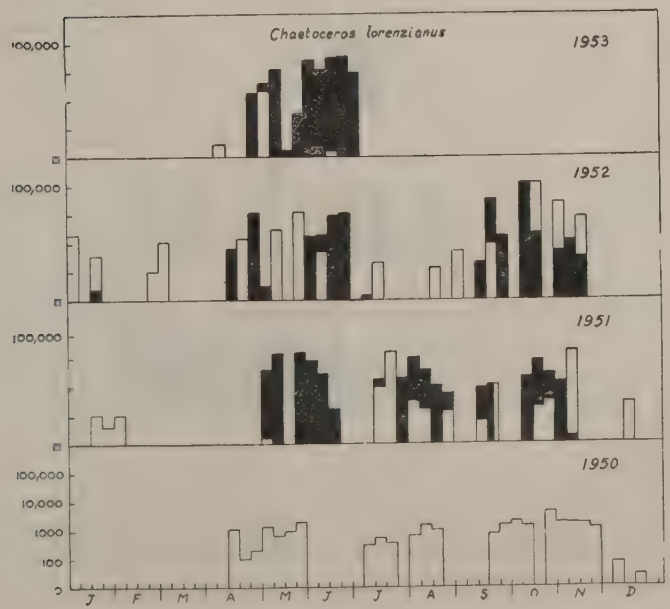

Chaetoceros lorenzianus
1953
1952
1951
1950
100,000
10,000
1000
100
0
J F M A M J J A S O N D

FIG. 7

It appeared in large numbers during the diatom blooms. *C. lorenzianus* together with *C. lascinosus* formed the bulk of *Chætoceros* abundance. The periods of peak production were more distinct in Palk Bay, one in May to June and the other in September to October. In the Gulf of Mannar as well as Palk Bay it showed a somewhat regular periodicity in occurrence, being common during the major peaks of the two areas. The largest catch of about 140,000 cells occurred in October 1952 at both stations.

Chætoceros debilis is the most abundant form of the genus in many of the temperate stations (Cupp, 1937). However, in our waters *C. lorenzianus* occupies the place when taken on a round-the-year basis though occasionally a stray catch of equally abundant or even slightly more of *C. lascinosus* may be obtained.

Chætoceros peruvianus Brightwell (Fig. 8) occurred commonly in the Gulf of Mannar from April to December at intervals. Season of persistent occurrence in successive years was November with a regular succession. In Palk Bay it was present in fairly large numbers from May to November with occasional breaks. The maximum abundance was in June with a total catch of 154,000 cells.

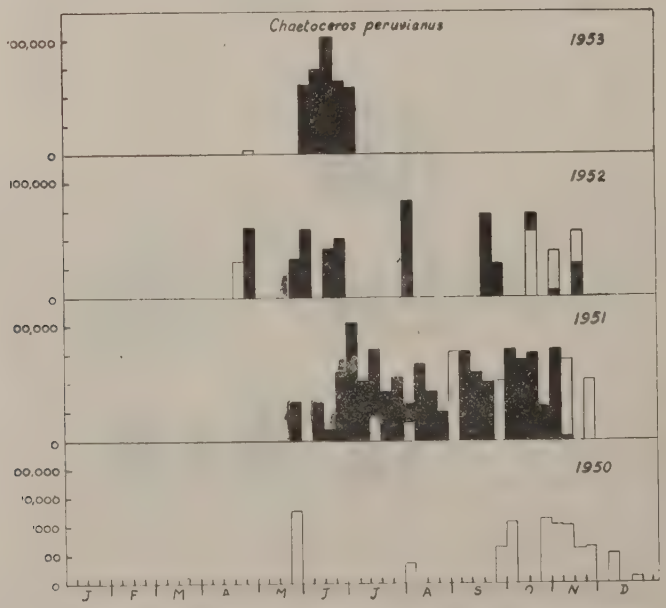


FIG. 8

. *Coscinodiscus gigas* Ehrenberg (Fig. 9) occurred in both places almost throughout the year in small numbers. In the Gulf of Mannar there was a feeble maximum in June 1950 but it was not a regular feature. In Palk Bay their occurrence seems to be a regular feature in July.

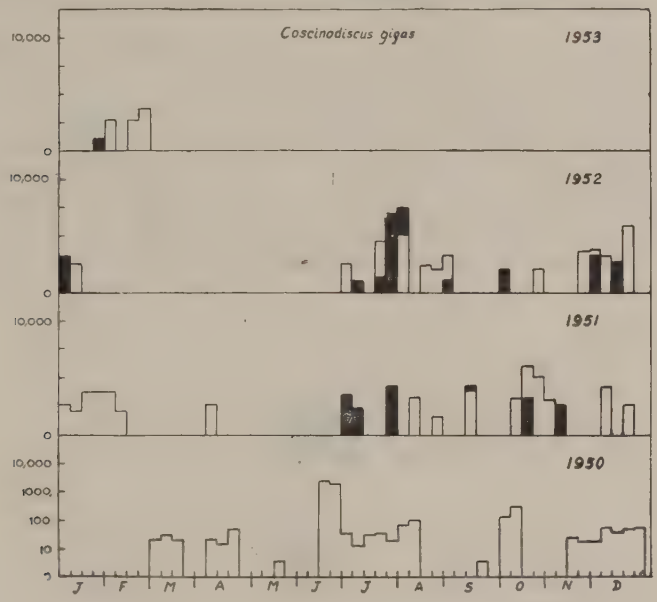


FIG. 9

Hemidiscus hardmannianus (Greville) Mann (Fig. 10) had a greater abundance in the Gulf of Mannar than in Palk Bay. It occurred throughout the year at intervals. From January to April it was very common in the plankton with maximum abundance in March to April during which period they occurred regularly indicating a distinct periodicity. In Palk Bay it was found only in small numbers along with other species during the two diatom maxima. The largest catch was 76,000 cells from the Gulf of Mannar in March 1951, while from Palk Bay it was only 800 cells during October in the same year.

Rhizosolenia alata Brightwell (Fig. 11) is a temperate oceanic species exhibiting wide fluctuation in its occurrence in both the areas. In the Gulf of Mannar during the year 1950 it was common in the plankton throughout the year excepting May and June with the maximum record of 319,000 cells

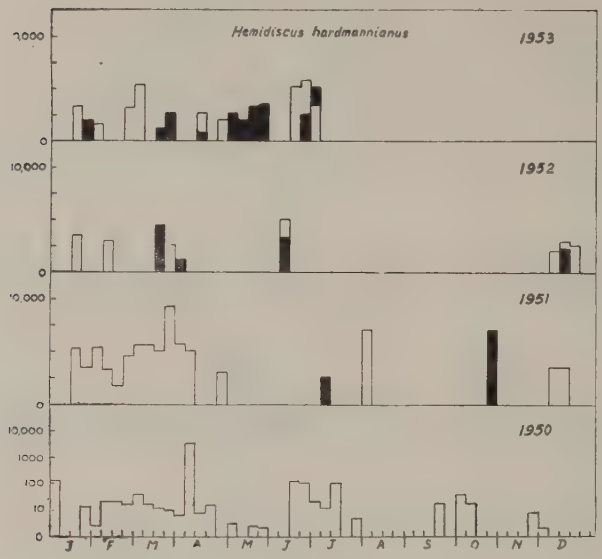

Hemidiscus hardmannianus
1953
1952
1951
1950
J F M A M J J A S O N D

FIG. 10

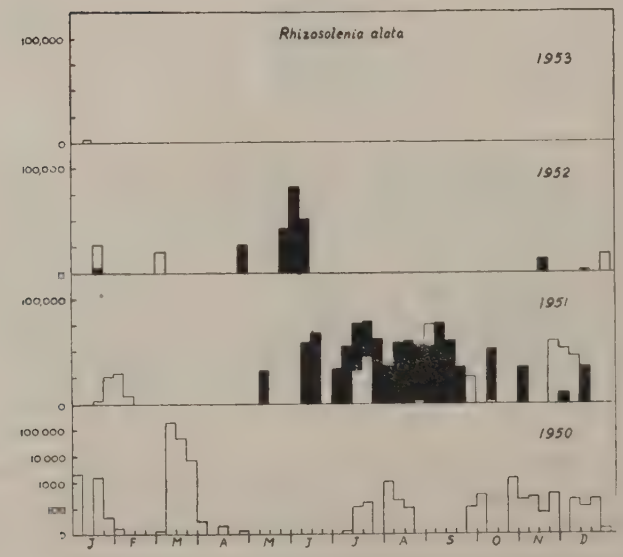

Rhizosolenia alata
1953
1952
1951
1950
J F M A M J J A S O N D

FIG. 11

in March. In the succeeding years it was comparatively less in abundance. In Palk Bay from June to September 1951 it occurred in large numbers with a regular periodicity in June. During the period covered by the present investigations, a progressive decrease in abundance was observed in both regions. Gough (1907) observed that it was always absent or, nearly always, at all the more neritic stations in the English Channel.

Rhizosolenia imbricata Brightwell (Fig. 12) occurred in the Gulf of Mannar at intervals. It was common in February or March and in November. In Palk Bay from June to September it was abundant and was the dominant member of the genus. A regular periodicity in its occurrence during January to March in Gulf of Mannar and in June and September in Palk Bay was also observed. In 1951 they were remarkably abundant at both places; the highest catch from the Gulf of Mannar was 29,000 cells in February while from Palk Bay it was 113,000 cells in July.

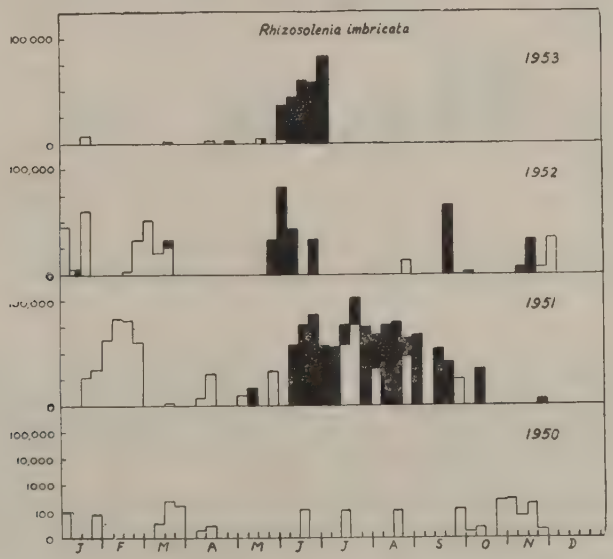


Fig. 12

Rhizosolenia styliformis Brightwell (Fig. 13).—A group of forms are met with in this species. But seasonal variations have been determined for the species as a whole. As observed by Delsman (1939), in the waters of Java, in the present instance too, this species had only a subordinate position in the plankton compared to the other species of *Rhizosolenia*.

Rhizosolenia styliformis occurred at intervals throughout the year in the Gulf of Mannar but it was more prominent during August to January. In Palk Bay the occurrence of *R. styliformis* was mainly restricted to the summer months. In both places a regular periodicity in its occurrence was observed. The highest catch from the Gulf of Mannar was 20,000 cells and from Palk Bay 8,000 cells.

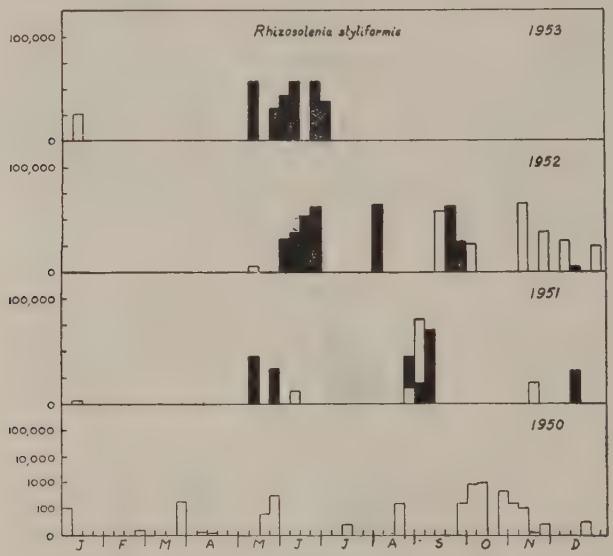


FIG. 13

According to Sproston (1949), *Rhizosolenia* spp. have a midsummer maximum wherever they occur. However, our observations are not quite in agreement with this, the maximum being between June and September.

Thalassionema nitzschioides Grunow (Fig. 14) though grouped as a north temperate neritic species, according to Smayda (1958) it is circumglobal and its distribution pattern supports the contention of some investigators that neritic species can survive in oceanic environments if transported there.

It occurred almost throughout the year in the Gulf of Mannar with occasional breaks. It was an abundant species in many of the months, with a maximum record of 336,000 cells in May 1950. During the succeeding years the peak was found to shift to the earlier part of the year. From

June to December also it was a frequent member of the plankton. In the frequency of occurrence and abundance it occupied an important place in the plankton of the Gulf of Mannar, whereas in Palk Bay, it was generally present only during the two major blooms with a probable succession in the summer months.

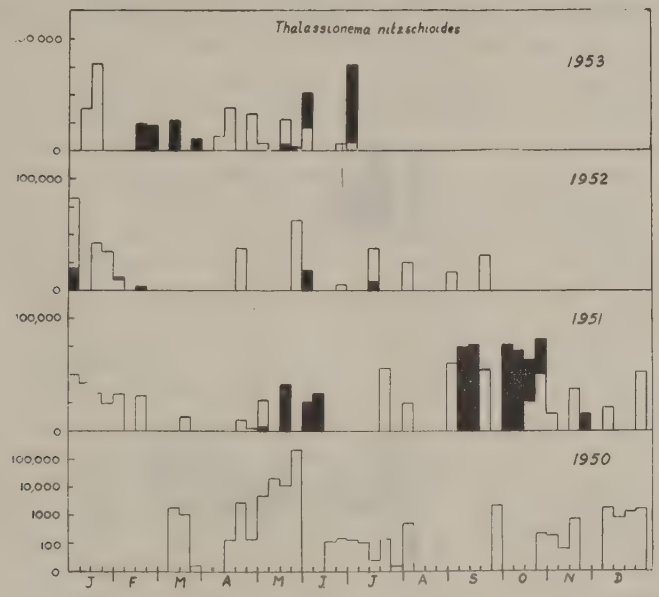


FIG. 14

Harvey *et al.* (1935) have stated that off Plymouth this species has a steady secondary importance throughout and forms the dominant member of the spring maximum. In Aomori Bay, Japan, Kokubo and Tamura (1931) found it sharing first place in the plankton, particularly near the surface, in October to November along with *Biddulphia* spp. Chacko (1950) has, however, recorded it as rare throughout the year around Krusadai Island in the Gulf of Mannar.

Thalassiothrix frauenfeldii Grunow (Fig. 15) is probably the most important species occurring in the plankton of both Palk Bay and the Gulf of Mannar. In the latter it appeared in large numbers almost throughout the year with short breaks. It was a dominant member of the summer bloom of both the stations. The peak production period in both the places appeared to be in May but in October also they were abundant.

Thalassiothrix frauenfeldii is considered as an oceanic temperate species preferring warmer waters. It is predominant in the coastal plankton of Mediterranean (Bernard and Fage, 1936) and in the Chu-San area it holds a third place in the winter, common in the spring and rare in the summer (Sproston, 1949). Fox (1929) noticed in East Pacific coast a phenomenal r se of *T. frauenfeldii* when other diatoms failed in the spring. Chacko (1950) also has observed that *T. frauenfeldii* with *T. longissima* occupies the first place in the plankton around Krusadai Island.

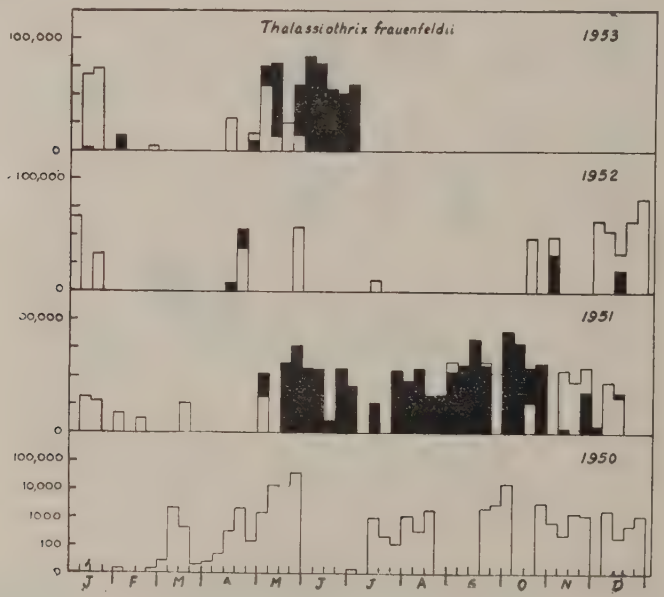


FIG. 15

DISCUSSION

Among the diatoms listed and discussed above, *Chætoceros* spp., *Rhizosolenia* spp. and *Thalassiothrix frauenfeldii* may be considered as persistent forms contributing substantially to the phytoplankton blooms and only these are found to exhibit regular periodicities in both the areas.

According to Bogorov (1958) seasonal variations in qualitative composition and abundance of organisms permit us to distinguish definite biological seasons. In general, the biological winter is characterised by a minimum of phytoplankton and the biological spring by a rapid multiplication of phytoplankton. In the subtropical regions the biological spring corres-

ponds to the month of May and the autumnal maximum occurs in November. As far as the regions, where the present observations were conducted are concerned, this biological spring is found to be also in May. In the Gulf of Mannar the "autumnal maximum" occurs in October or November, while in the Palk Bay the abundance due to spring outburst persists till October except for a slight decimation in July to August (Prasad, 1956).

From the classified list, it may be observed that the local flora of the two inshore stations are mostly composed of neritic species. Oceanic species of the genus *Rhizosolenia* and *Thalassiothrix frauenfeldii* only are exceptions. Littoral forms, excepting *Pleurosigma* spp., are only occasionally met with, and are often more abundant, as is to be expected, during or immediately after a period of turbulence. While reviewing the probable seasonal succession of the more important species in the South-West Atlantic, Hart (1934) has classified them into (i) spring forms; (ii) forms with a spring maximum but which remain more or less important throughout the season; (iii) forms with spring and autumn maxima, and (iv) a few comparatively unimportant forms found most frequently in late summer and autumn. Based on the above grouping it may be said that most of the species considered here come under the second category, while *Chætoceros indicus*, *C. lascinosus* and *Bacteriastrum* spp. are found to be with a distinct spring and autumn maxima, thus falling in the third category.

Palk Bay being a more or less enclosed area, several of the tropical and south temperate species which occur there exhibit regular periodicities. The relatively more regular seasonal variations and succession exhibited by these species may be an indication of a larger autochthonous breeding stock of diatoms in this area.

On the other hand Gulf of Mannar is more conspicuous in oceanic species like *Biddulphia sinensis*, *Chætoceros coarctatus*, *Hemidiscus hardmannianus*, etc., which have a round-the-year distribution. The information available in literature on the currents of this area suggests the possibility of influx of water of oceanic origin, by horizontal transport, during February to March (*see* also Prasad, 1954). This may also be in some way responsible for the instances of local flowering of single species of diatoms reported by Prasad (1954). It may be worthwhile to note in this context that Ruud (1932) commented on the fact that regions with converging currents tend to encourage a rich production of plankton and Hart (1934) remarked that the influence of the mixing of the currents may be the determining factor in the localizations observed in the Weddel Sea area. Hardy, in Hardy and Gunther (1935), has further suggested that the rich production in regions

with converging currents is due to the stimulus to growth consequent upon slight changes in the external conditions of the environment. Bigelow, Lillick and Sears (1940), who have noted local flowerings of *Rhizosolenia alata* and *Chætoceros* in shoal water close to land in the Gulf of Maine even in early mid-winter, conclude that temporary enrichment of the water with planktonic vegetation is not an exceptional event in shoal water even in seasons when phytoplankton is scarce, as these flowerings were observed in such short record of observations. Wood (1959) is of the opinion that vertical mixing of surface muds and the waters of the continental shelf is responsible, in part, for the neritic blooms of phytoplankton.

From the analyses of the intensity and occurrence of the different groups of diatoms, it can be seen that some of the most abundant, persistent and dominant varieties are those which have been grouped by Cleve and others as Temperate Species. Smayda (1958) remarked that Cleve overemphasised the role of visiting species in contributing to and moulding the seasonal phytoplankton cycle and attributed the seasonal changes in composition and dominance of the community to the periodic recruitment of species from different areas. He supports the view of Gran (1912) that when conditions of existence in the flowing water-masses gradually alter, it is the new conditions of existence that decide the character of flora, since the species best qualified to endure them will very soon get the upper hand over the others, and adds that the seasonal composition of a developing population is derived primarily from a local stock and secondarily from visitors.

In the complex of interdependent factors governing the seasonal variations and yearly fluctuations in phytoplankton production, transportation by surface currents is a significant one. Currents from the south temperate regions reach these areas only during October to January (Sewell, 1937) and the monsoon drift from June to August (Prasad, 1954). So if these temperate species have their normal distribution in temperate regions and are carried by the water-masses they would reach here only during these months. But their occurrence, in other months also, makes one feel that most of these temperate species are really ubiquitous. This is not altogether improbable since this grouping is based mainly on collections made during expeditions and very little was known of the seasonal distribution of diatoms in the tropical regions. The occurrence of these so-called temperate species in such large numbers during the greater part of the year in areas outside the temperate regions makes one doubt the validity of this grouping. As for the classification of species into neritic and oceanic, Smayda (1958) is of the opinion that such a classification places the species in an undefined

region and tells nothing of its life cycle or why it is found there and hence even these bio-geographical terms should be rejected. All these indicate that in many cases our concepts of species habits and habitats need to be broadened.

Summary

Forty-nine out of the fifty-one species of diatoms occurring commonly in the plankton of Mandapam area have been classified into bio-geographical groups and the general character of the diatom flora of the Gulf of Mannar and Palk Bay is described.

The seasonal variations and periodicities exhibited by fifteen species, which are well-represented in the plankton have been compared for both the places. It is found that the biological spring falls in May and the 'autumnal maximum' occurs in October or November. Most of these species are forms with a spring maxima but which remain more or less important throughout the season while a few are with a distinct spring and autumn maxima.

The data suggest that Palk Bay is having a larger breeding stock of autochthonous diatoms which are mostly neritic, whereas in the Gulf of Mannar there are more oceanic diatoms.

The validity of the existing bio-geographical grouping of some of the species of diatoms and the necessity of widening the concept of species habits and habitats are mentioned in the light of the available data.

References

Allen, W. E. 1945 .. Seasonal occurrence of marine plankton diatoms off Southern California in 1938. *Bull. Scripps Inst. Oceanogr.*, **5**, 293–334.

Bernard, F. and Fage, L. 1936 Recherches quantitatives sur le plankcton Mediterranena (note preliminaire). *Bull. Inst. Oceanogr. Monaco*, No. 701, 1–20.

Bigelow, H. B., Lillick, L. C. and Sears, M. 1940 Phytoplankton and planktonic protozoa of the off-shore waters of the Gulf of Maine. *Trans. Amer. Phil. Soc., N.S.*, **31**, 149–91.

Bogorov, B. G. 1958 .. Perspectives in the study of seasonal changes of plankton and of the number of generations at different latitudes. *Perspectives in Marine Biology*, Edited by A. Buzzati-Traverso, University of California Press, pp. 621.

Chacko, P. I. 1950 .. Marine plankton from waters around the Krusadai Island. *Proc. Indian Acad. Sci.*, **31 B**, 162–74.

Cupp, E. E. 1937 .. Seasonal distribution and occurrence of marine diatoms and dinoflagellates at Scotch Cap, Alaska. *Bull. Scripps Inst. Oceanogr. Tech. Ser.* **4**, 71–100.

Delsman, H. C. 1939 .. Preliminary plankton investigations in the Java Sea. *Treubia*, **17,** 139–81.

Fox, D. 1929 .. Quantitative studies on inshore marine diatoms and dinoflagellates taken at five stations on the East Pacific Coast. *Bull. Scripps Inst. Oceanogr.*, **2,** 189–96.

Gough, L. H. 1907 .. Report on the plankton of the English Channel in 1904 and 1905. *Inst. Invest. Mar. Biol. Assoc. Rep.*, **2,** 161–268.

Gran, H. H. 1912 .. Pelagic *Plant Life. Depths of the Ocean by Murray and Hjort*, Macmillan & Co., London, pp. 821.

Hardy, A. C. and Gunther, E. R. 1935 The plankton of the South Georgia Whaling grounds and adjacent waters, 1926–27. *Discovery Rep.*, **11,** 1–456.

Hart, T. J. 1934 .. On the phytoplankton of the South-West Atlantic and the Bellingshausen Sea. *Ibid.*, **8,** 3–268.

Harvey, H. W., Cooper, L. H. N., Lebour, M. V. and Russel, F. S. 1935 Plankton production and its control. *J. Mar. biol. Assoc. U.K.*, **20,** 407–44.

Kokubo, S. and Tamura, T. 1931 A quantitative investigation of the plankton of Aemori Bay, as studied comparatively by pump and net collection. *Sci. Rep. Tohoku Imp. Univ.* (Ser. 4, Biol.), **6,** 491–531.

Lebour, M. V. 1930 .. *The Plankton Diatoms of Northern Seas.* Ray Society, London, pp. 244.

Prasad, R. R. 1954 .. The characteristics of marine plankton at an inshore station in the Gulf of Mannar near Mandapam. *Indian J. Fish.*, **1,** 1–36.

———. 1956 .. Further studies on the plankton of the inshore waters off Mandapam. *Ibid.*, **3,** 1–42.

Ruud, T. J. 1932 .. On the biology of Southern Euphausiidæ. *Hyalradets Skrifter* (*Norske Vid.-Akad.* Oslo), **2,** 1–105.

Sewell, R. B. S. 1937 .. The ocean round India. *Indian Sci. Congr. Assoc.* Silver Jubilee Session, 1938, 17–41.

Smayda, T. J. 1958 .. Bio-geographical studies of marine phytoplankton. *Oikos*, **9** (2), 158–91.

Sproston, N. G. 1949 .. A preliminary survey of the plankton of the Chu-San region, with a review of the relevant literature. *Sinensia*, **20,** 58–161.

Subrahmanyan, R. 1946 .. A systematic account of the Marine Plankton Diatoms of the Madras Coast. *Proc. Indian Acad. Sci.*, **24 B,** 85–197.

Wood, E. J. F. 1959 .. Some aspects of marine microbiology. *J. Mar. biol. Ass. India*, **1,** 26–32.

STUDY OF BOMBAY PRAWNS

The Seasonal Fluctuation and Variation in Abundance of the Commercially Important Species of Bombay Prawns with a Brief Note on Their Size, State of Maturity and Sex Ratio

By (Miss) F. S. Shaikhmahmud* and V. B. Tembe‡

(Zoology Department, Institute of Science, Bombay)

Introduction

The present paper is the result of investigations carried out during the period July 1952 to July 1954 and deals with the study of commercially important species of prawns found in the inshore area of Bombay region and the seasonal fluctuations as well as the variation in abundance during the different months of the year.

With the exception of the work done by Chopra (1943) and Rai (1933), practically no other information is available about the Prawn Fishery of Bombay, though much work has been done on the Prawn Fishery of Malabar Coast. In this connection, mention must be made of Panikkar (1937) and Menon (1953, 1955–57).

Material and Method

Material for this investigation was collected by random sampling of commercial catches twice a week from the nearest landing place, *viz.*, Sassoon Docks. In this laboratory the catch was examined for the correct systematic position of prawns according to Alcock (1906), Anderson and Linder (1943), Borradaile (1915), Burkenroad (1934), Henderson and Matthai (1910) and Kemp (1914 and 1925); the size of the prawn, sex and gonad conditions were also noted. The length was measured from the tip of the rostrum to the tip of the telson. Almost all the commercially important species found in Bombay waters have been recorded except those which were found to be few in number. Such species have been grouped together under the heading miscellaneous.

The prawns that were landed at Sassoon Docks were caught either at Karanja and Uran situated in Dharamtar creek, or at the mouth of Bombay

* Present address: Central Marine Fisheries Research Station.

‡ Biology Department, Elphinstone College, Bombay-1.

harbour. They were available throughout the year. The grounds from where the catch was brought were situated between 3–7 miles from the shore. The depth of water ranged from 4–9 fathoms.

Gear used.—The 'Dol' net or bag-net was the gear used for catching prawns and Bombay ducks along with other small fishes. The net is made of either cotton yarn or hemp. The small nets which varied in size from 35′–50′ in length with a mesh size from $\frac{1}{2}$″–2″ is known as "Bokshi"; whereas the others commonly termed 'Dol' nets may vary from 130′–150′ in length. The 'Dol' net is conical in shape, with an open rectangular mouth. The mouth is kept open by tying the ends, either to poles or to weights. The net is lowered to the bottom and orientated in such a way as to allow tidal currents to flow through it. Mesh size varied from $\frac{1}{2}$″–4″ in width. Fishing is carried out at any time of the day and night depending upon the tide. The duration of the haul lasts about $1\frac{1}{2}$–4 hours. The details of the 'Dol' nets and its operation have been described by Setna (1949 and 1954).

Seasonal Variations

The detailed study of the catch analysis for the years 1952–53 and 1953–54 revealed that the principal landings at Sassoon Docks consisted of *Parapeneopsis stylifera* 26·4%, *Metapenæus brevicornis* 12·8%, *Penæus indicus* 12·6%, *Metapenæus affinis* 12·3%, Miscellaneous 7·3%, *Metapenæus monoceros* 7%, species of *Leander* and *Hippolysmata* 6·7% and 5% respectively; *Parapeneopsis maxillipedo* 4·5%, *Parapeneopsis sculptilis* 3·9% and *Penæus carinatus* 1·5%. The above percentages are the average figures for the two years calculated by the number of specimens.

Penæus

The genus *Penæus* was represented by *P. carinatus* and *P. indicus*. Generally th se species occur regularly during the course of the year. Figure 1 shows the variation in abundance of the above two species in different months of the year. Both, considered together, appeared abundantly during September, October and November. *P. carinatus* measured from 10–15 cm. in length. They were found nearly for seven months but never in great numbers and were totally absent in the months of January, April, May, June and July. *P. indicus*, one of the commercially important species, was available throughout the year except during the months of January, July and August. Specimens ranged from 4·5–12·5 cm. in length and at times from 18–20 cm.

Metapenæus

The genus *Metapenæus* was represented by three species. Figure 2 shows the relative abundance of *M. monoceros*, *M. affinis* and *M. brevicornis* which

were invariably found together in the collections. All the three species seem to be permanent inhabitants of the Bombay waters contributing substantially to the prawn fishery. *M. monoceros* was found in fairly large

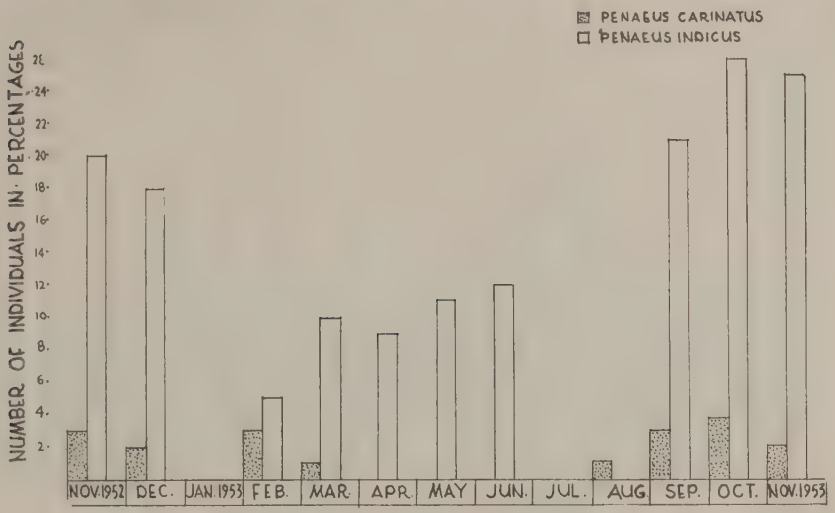


FIG. 1. Variation in abundance of *Penæus carinatus* and *Penæus indicus*.

quantities during rainy season, *i.e.*, July and August. Later there was a decline in their occurrence. They measured 4–12 cm. in length. One of the dominant species of *Metapenæus*, viz., *M. affinis* was available throughout the year. They were found in good quantities during January, February and March. Then there was a slight fall in April while a slight rise was noticed during May. They measured from 4·5–15·6 cm. in length. *M. brevicornis* followed more or less the same trend as *M. affinis*. They measured from 4–11 cm. in length. All the three species together contributed nearly 30–32% of the prawn catches.

Parapeneopsis

The species of *Parapeneopsis*, occurring in this area, were *P. stylifera*, *P. sculptilis* and *P. maxillipedo*. Figure 3 shows the variation in abundance of the above species. *P. stylifera* was ranked first in abundance amongst the available prawns. They measured from 5–14·5 cm. in length. *P. sculptilis* occurred in small quantities throughout the year, the highest percentage record was 7 and the lowest was 2. The sizes ranged from 4·3–

7·2 cm. *P. maxillipedo* had the same trend as *P. sculptilis*. They measured from 6–15·2 cm. in length.

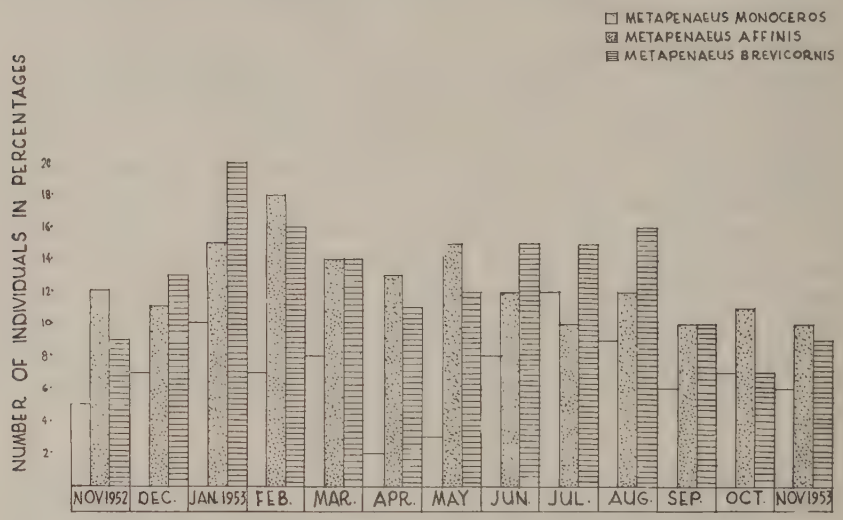


FIG. 2. Variation in abundance of *M. monoceros*, *M. affinis* and *M. brevicornis*.

Leander, Hippolysmata and Miscellaneous

Figure 4 explains the variation in abundance of the prawns belonging to two genera *Leander* and *Hippolysmata*, and a group of miscellaneous prawns.

The species belonging to this group are not of great commercial importance, and hence have been grouped separately. The genus *Leander* included *L. tenuipes* and *L. styliferus* while *Hippolysmata* included *H. ensirostris* and *H. punctata*. The miscellaneous group consisted of *Penæus canaliculatus*, *Metapenæus dobsoni*, *Parapeneopsis uncta*, *Solenocera indicus*, *Leander carinatus*, *Hippolysmata dentata*, *Palæmon carcinus*, *Palæmon malcolmsoni*, *Palæmon idæ*, *Latreutes mucronatus* and species of *Alpheus*. *Leander* was present during the major part of the year. They measured from 2·5–4 cm. in length.

Regular inhabitants of Bombay waters

It is evident from the foregoing account and Figs. 1, 2, 3 and 4 that the permanent inhabitants of the inshore area were *M. monoceros*, *M. affinis*, *M. brevicornis*, *P. stylifera*, *P. sculptilis* and *P. maxillipedo* which were found

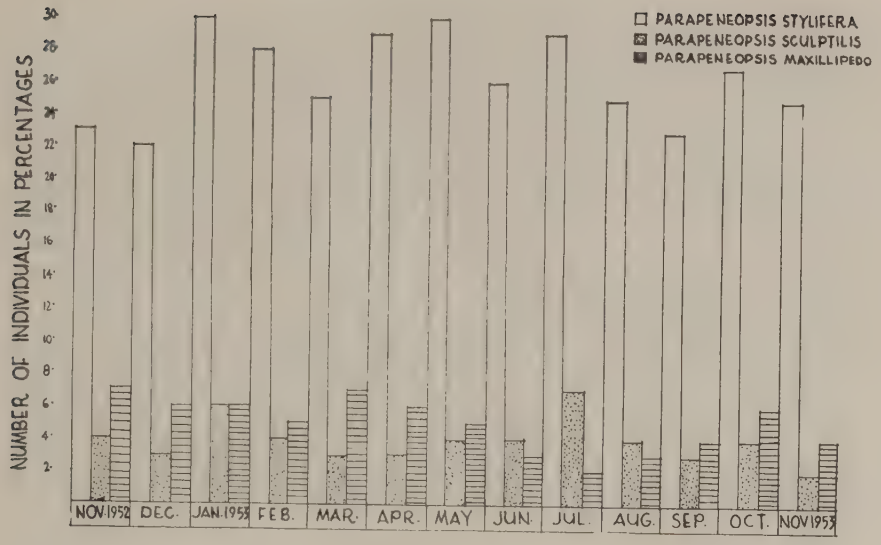


FIG. 3. *Variation in abundance of P. stylifera, P. sculptilis* and *P. maxillipedo.*

throughout the year. All the others were visitors to this area and the period of their visit varied for different species.

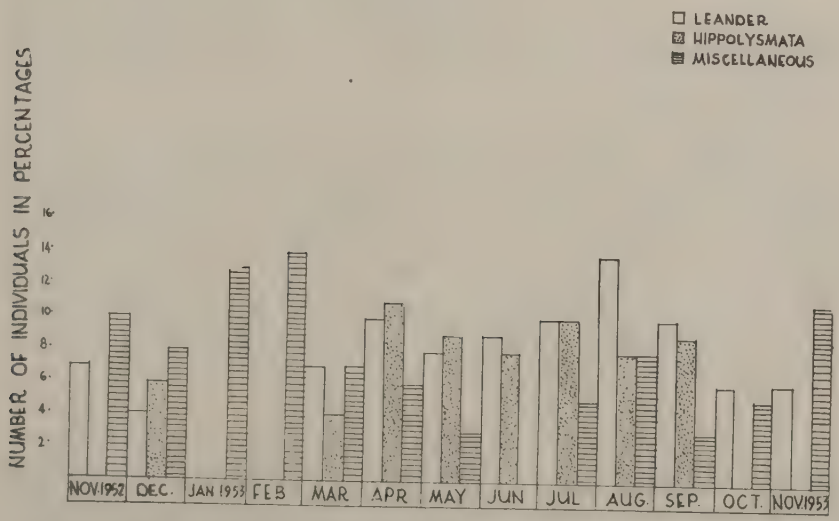


FIG. 4. Variation in abundance of *Leander, Hippolysmata* and miscellaneous.

Regular visitors

P. carinatus was found from August–December and then again in February and March; while *P. indicus* was recorded in large numbers usually after heavy rains, *i.e.*, during September–December, and in comparatively small quantities before heavy rains, *i.e.*, beginning from February–June. But *P. canaliculatus* was found during January–March. *Solenocera indicus* gradually appeared in November and indicated a prolonged stay for nearly seven months, while *Acetes indicus** were recorded during summer and monsoon. The species of *Hippolysmata* and those of *Leander* were found to be temporary residents of this area immigrating for the purpose of breeding. When they come in large schools, they are beaded or berried and hence might have migrated for the purpose of spawning. However, our observations contradict those of Kemp (1917), that *L. styliferus* migrates towards the estuaries and tidal rivers possibly for breeding purposes. But they are in agreement with Forster (1951 *a*) suggesting thereby that *Leander* migrates seawards for the purpose of breeding.

Irregular visitors

There were some species of prawns which were not common in the inshore area of Bombay waters and did not contribute materially to the prawn fishery. They were *L. mucronatus*, *L. serrifer* and *L. mani*. Lastly, *P. carcinus*, *P. malcolmsoni* and *P. idæ* were not the inhabitants of this area, but seemed to have been dragged here along with the force of water current, as this time of the year (July) rivers were in spate, on account of heavy rains.

Biological investigations

Designation of stages in the growth cycle.– On analysis of the catches in general and the examination of gonads in particular it was possible to separate the animals into three main groups: (i) Immature or young, (ii) Maturing or the one which has not yet reached the adult stage and (iii) Mature or the adult ones. The following criteria were taken into account.

1. The gross study of the animal with respect to its length and weight.
2. The development of the secondary sexual character and
3. The study of the gonad macroscopically.

---

* *Acetes indicus.*—This small species did not occur in our samples and hence has not been included in the catch analysis; but has been mentioned above because of field observations and hence has been grouped as regular visitor. The absence of *A. indicus* may be attributed either to the sorting of prawns on the boat or due to the fact that when prawn landings are good, they throw away small varieties into the sea. (Information supplied by local fishermen.)

Stage I—Immature.—In males the andricum is not fully developed and testes are not at all visible (with the help of hand-lens). In females though the thelycum is fully developed, ovaries are thread-like, small and pigmentless.

Stage II—Maturing.—In males andricum is fully developed, the testes are visible as small rounded masses, testes lobes not yet formed. In females, the thelycum is fully developed; ovaries are well developed with well-marked pigmentation and granulations.

Stage III—Mature.—In males the andricum and the testes are fully developed and the presence of appendices masculina on the second pleopod is conspicuous. The presence of the spermatophores at the base of the fifth thoracic legs is noticed without any difficulty. (This may be absent in the case of spent animal.) Whereas in the case of females, the ovarian lobes are well defined, and are visible through the carapace. The ovary is deeply pigmented and occupies most of the space in the cephalothorax and is densely packed with large-sized ova. The ovaries are seen clearly with the naked eye through the carapace; and are dark green in colour.

The above stages have been defined with the help of detailed macroscopical and microscopical studies and all the anatomical and histological details will be published later.

Sex ratio and stages of gonad development

The sex ratio (number of males/females) and the sexual development of prawns studied from the commercial samples of 1952-53 have been recorded in Table I. It may be noted that the prawns of the *Penæus* group, *viz.*, *P. carinatus* and *P. indicus* were mostly found to be in the immature state. However, a few female specimens belonging to *P. indicus* were recorded in the mature state. As regards the sex ratio of *P. indicus* it was observed that in the month of November females were more in number than the males.

In the case of *M. monoceros* the sex ratio was found to be somewhat uniform throughout the year. Females were predominant over the males except in the month of June, when it was recorded as equal number of males to females. Neither females nor males were found to be in the mature state.

It is interesting and illuminating to note that though *M. monoceros* do not attain maturity in this area, *M. affinis* is found to reach maturity. All the three stages, *viz.*, immature, maturing and mature prawns were recorded amongst the latter. As regards the sex ratio, females were more in number throughout the year, and especially during the months of October, November

TABLE

No.	Name of species	Occurrence of different stages in the inshore area of Bombay	SEX 1952 Nov. ♂	Nov. ♀	Dec. ♂	Dec. ♀
1	*Penæus carinotus** ..	Mostly immature, both males and females	..	..	..	..
2	*Penæus indicus* ..	Almost all males immature, very few mature females, were recorded in the months of November and December	42	58	49	51
3	*Metapenæus monoceros* ..	All the males and females were in the immature state	40†	60	43†	67
4	*Metapenæus affinis* ..	All the three stages, *viz.*, immature, maturing and mature were recorded for both the sexes	35	65	30	70
5	*Metapenæus brevicornis* ..	Most of the males were mature but females were either immature or maturing	41	59	44	56
6	*Parapeneopsis stylifera* ..	All the three stages of both the sexes were found throughout the year. Few spent females were also recorded	50	50	52	48
7	*Parapeneopsis sculptilis** ..	Mostly immature males, very few mature females were recorded	..	..	..	..
8	*Parapeneopsis maxillipedo* ..	All the three stages were recorded for the sexes	..*	..	33	67
9	*Solenocera indicus** ..	Only immature were recorded	..	..	..	..
10	*Leander tenuipes* ..	Mostly mature (berried) females were found during March to May	Data not available		Data not available	
11	*Hippolysmata ensirostris* ..	Mostly mature (berried) females were found	Absent		20‡	80

and December; and then again April, May and June, when greater number of females were found to be in the maturing and mature state.

It is evident from the present study that the males of *M. brevicornis* attained maturity while females did not in this area. Yet many maturing

RATIO %

1953

Jan. ♂	Jan. ♀	Feb. ♂	Feb. ♀	March ♂	March ♀	April ♂	April ♀	May ♂	May ♀	June ♂	June ♀	July ♂	July ♀	Aug. ♂	Aug. ♀	Sept. ♂	Sept. ♀	Oct. ♂	Oct. ♀
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Absent		48	52	44	56	55	45	53	47	58	42	Absent		45	55	35	65	45	55
45	55	48†	52	44†	56	49†	51	47†	53	50	50	45	55	40	60	42†	58	44†	56
40	60	45	55	47	53	33	67	37	63	31	69	40	60	47	53	51	49	43	57
51	49	50	50	43	57	33	67	35	65	37	63	43	57	45	55	44	56	42	58
44	56	39	61	34	66	37	63	29	71	45	55	52	48	53	47	49	51	51	49
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..*	..	..*	..	40	60	45	55	43	57	..*	..	..*	..	..*	..	..*	..	..*	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Absent		..*	..	5	95	All	♀	All	♀	All	♀	10	90	30	70	18	82	..*	..
Absent		Absent		35	65	25	75	20	80	15	85	All	♀	All	♀	All	♀	Absent	

* Sex ratio not calculated because of meagre number.
† Number was less than 100.
‡ Number was less than 60.

and impregnated females were encountered. In the light of present knowledge, it may be said that females may be migrating away from the shore

(exploited area) towards the deeper waters. Throughout the year females were predominant except in the month of February.

The detailed study of reproductive organs of *P. stylifera* (Shaikhmahmud and Tembe, 1958) reveals that it differs from *Penæus* and *Metapenæus* on the following aspects: (i) development and the structure of spermatophores, (ii) breeding seasons, and (iii) sex ratio. It is evident from Table I that females were predominant only for six months. The occurrence of females in greater numbers during the period February–June coincides with the peak of their breeding season (unpublished record) in this area, which falls during March, April and May with a high fat content (Shaikhmahmud and Magar, 1957). All the three stages of both the sexes were found throughout the year. A few spent females were also recorded.

As the number of specimens obtained from the catches are not sufficient to calculate the sex ratio throughout the year, it is difficult to compare *P. maxillipedo* with *P. stylifera*. However, it is evident that they do attain maturity in this area, and are not migratory for the purposes of breeding. In this respect the above findings are in perfect agreement with those of Menon (1952) and Chopra (1943).

Although *S. indicus* is available for about six to seven months, they are found to be in the immature state.

Amongst *L. tenuipes* and *H. ensirostris* also females are predominant over males or at times the whole sample may constitute entirely of females. Mature females were recorded in the months of December and March–September.

Discussion

During the course of investigation, prawns never failed to occur in weekly collections except on the days of very heavy rains or on the days of festivals when fishermen did not go out for fishing. It is, therefore, obvious that prawns occur in the coastal water of Bombay throughout the year with a few periodical inter- and intra-specific variations as shown in Figs. 1, 2, 3 and 4. Moreover, the present study reveals that there are periods of occurrence of maxima and minima as seen in the accompanying figures.

Rai (1933) in an article on "Shell Fishery of Bombay Presidency" has recorded *Penæus semisulcatus* (DeMan), *Leander styliferus* (M. Edw.) and *Metapenæus lysianassa* (DeMan) as some of the common species of Bombay. But we have not come across even a single specimen of *M. lysianassa* in

Bombay waters during our investigations while *P. semisulcatus* and *L. stylifer us* are not common. Not only have the present studies brought to light some species unrecorded from this area, such as *P. canaliculatus*, *M. affinis*, *P. maxillipedo*, *S. indicus*, *H. ensirostris*, etc., but also proved that a few of the species previously regarded as common are either very rare or totally absent.

It is evident from the foregoing account and the data recorded in Table I that male and female prawns never occur in equal proportions in the commercial catches but vary considerably from month to month and probably from species to species and also from a slightly predominant male to an entirely female population. According to Racek (1956), it may even vary from ground to ground and in different areas, and hence the importance of its study. In general, our results are in agreement with Menon (1957).

At this stage it is difficult to comment upon the breeding habits and the breeding grounds of *Penæid* prawns. The present investigations, however, throw some light on the habits and habitats of a few species of great economic importance. *P. carinatus*, *P. indicus*, *M. monoceros*, *P. sculptilis* females of *M. brevicornis* and *S. indicus* were found to be in the immature state, whereas males of *M. brevicornis* were found to reach maturity in this area. The impregnated females of the latter revealed that the mating may be taking place in shallow water. After that females leave the ground for maturation and spawning. It would seem that *M. affinis*, *P. stylifera* and *P. maxillipedo* prefer areas of soft mud, rich plankton and shallow coastal waters, where they mate and spawn. Indications to the existence of such conditions have been recently described for coastal areas of Bombay by Carruthers *et al.* (1959). It is necessary to confirm this indirect observation with the help of extensive plankton and biochemical studies.

Summary

The study of Bombay prawns was undertaken during the period July 1952 to July 1954 to ascertain the different species of prawns found inhabiting the coastal area of Bombay waters.

The seasonal fluctuations as well as variation in abundance of various commercially important species have been studied and a brief account of the results of investigation of species mainly contributing to the Prawn Fishery of Bombay for their size, state of maturity and sex ratio have been given.

Unlike other parts of India, prawn fishing is carried out throughout the year, but the different species have their own seasons of abundance and scarcities. These facts have been illustrated in Figs. 1, 2, 3 and 4.

The authors wish to express their thanks to Dr. D. V. Bal, Director, Institute of Science, Bombay, for giving the necessary facilities and encouragements throughout this work. They are also thankful to Shri M. Krishna Menon, Research Officer (Prawns), Central Marine Fisheries Research Station, for his valuable suggestions.

References

1. Alcock, A. 1906 .. Prawn of the Penæus group. *Catalogue of Indian Decapoda Crustacea*, **3**, 1.

2. Anderson and Linder. 1943 .. A provisional key to the Shrimps of the family Penæidæ with special reference to American forms. *Trans. American Fish. Soc.*, **73**.

3. Borradaile, L. A. 1915 .. Notes on Carides. *Ann. Mag. Nat. Hist.*, **6**, 7.

4. Burkenroad, M. D. 1934 The Penæidæ of Louisiana with a discussion of their world relationship. *Bull. American Mus. Nat. Hist.*, **68**.

5. Chopra, B. N. 1943 .. Presidential Address to the Section of Zoology and Entomology of the Indian Science Congress.

6. Carruthers, J. N., Gogate, S. S., Naidu, J. R. and Laevastu, J. 1959 Shorewards upsole of the layer of minimum oxygen off Bombay, its influence on marine biology, especially fisheries. *Nature*, **183**, 1084–87.

7. Handerson and Matthai. 1910 On certain species of Palæmon. *Rec. Indian Mus.*, **5**, 277–305.

8. Kemp, S. 1914 .. Notes on Crustacea Decapoda in the Indian Museum Hippolytidæ. *Ibid.*, **10**, 81–120.

9. ————. 1925 .. Notes on Crustacea Decapoda in the Indian Museum on various Caridæ. *Ibid.*, **27**, 249–307.

10. Menon, M. K. 1953 .. Notes on the bionomics and fishery of the prawn *Parapeneopsis stylifera*. *J. Zool. Soc. India*, **5** (1), 153–62.

11. ————. 1955 .. Notes on the bionomics and fishery of the prawn *Metapenæus dobsoni* on the South-West Coast of India. *Indian J. Fish.*, **1** (2), 41–56.

12. ————. 1957 .. Contributions to the biology of Penæid prawns of the South-West Coast of India, I. Sex ratio and movements. *Ibid.*, **4** (1), 62–74.

13. Panikkar, N. K. 1937 .. The prawn industry of Malabar Coast. *J. Bombay Nat. Hist. Soc.*, **39**, 343–53.

14. Racek, A. A. 1956 .. Penæid prawn fisheries of Australia with special reference to New South Wales. *Proc. Indo-Pacific Fish. Counc.*, Sec. **3**, 347–59.

15. Rai, H. S. 1933 .. The Shell Fisheries of Bombay Presidency. *J. Bombay Nat. Hist. Soc.*, **36,** 887–97.

16. Setna, S. B. 1949 .. Bombay fishermen's ingenuity. *Ibid.*, **48** (3), 444–49.

17. ————. 1954 .. In Quest of Bombay Duck. *Illustrated Weekly of India.* **75** (35), 24–25. August.

18. Shaikhmahmud, F. S. and Tembe, V. B. 1958 Study of Bombay Prawns. The reproductive organs of *Parapeneopsis stylifera* (M. Edw.). *J. Univ. of Bombay*, **27** (3), 99–110.

19. ——— and Magar, N. G. 1957 Studies in the Nutritive value of Bombay Prawns. Part I. Chemical composition of prawns. *J. Sci. Indust. Res. Jan.*, **16 A** (1), 44–46.

BIOLOGY AND FISHERY OF 'CHOO PARAI', *SELAROIDES LEPTOLEPIS* (CUVIER AND VALENCIENNES)

1. Food and Feeding Habits

By K. K. Tandon*

(*Central Marine Fisheries Research Station*)

Introduction

Carangids form a commercially important group of fishes in India but very little work has been done on their biology. The few available references to the subject being those of Chacko (1949), Mahadevan (1950), Datar (1954), Kuthalingam (1955 *b*), Chacko and Mathew (1956) and Vijayaraghavan (1957) on various species of horse-mackerel. The author, therefore, took up the study of *Selaroides leptolepis* (Cuv. & Val.), one of the common food Carangids of the Gulf of Mannar and the Palk Bay in the vicinity of Mandapam. The work was initiated in May 1957 and was carried out at the Central Marine Fisheries Research Station, Mandapam Camp. The present paper deals with the food of this fish.

Material and Methods

The material was collected weekly from Pudumadam and Rameswaram Road on the Gulf of Mannar and Thangachimadam and Rameswaram on the Palk Bay depending upon the fishing season, except on certain occasions when samples were available only fortnightly or monthly. A sample of 30–50 fish comprising different size-groups was brought to the laboratory each time for complete analysis. Shore-seines ('kara valai' and 'ola valai') and bag-nets ('madi valai') accounted for the catch of fish.

Each fish was examined in the fresh state for length, weight and stage of maturity except on two occasions when the analysis was done on the preserved material. The fresh fish after preliminary examination were numbered, dated and preserved in 5% formalin for further studies. The fork length—taken from the tip of the lower jaw to the tip of the shortest fin ray in the caudal fork—is used for all calculations.

To analyse the food of *S. leptolepis* Points method (Swynnerton and Worthington, 1940; Frost, 1943; Hynes, 1950) was used. The percentage frequency of each item was determined by the Occurrence method.

---

* Government of India Senior Research Scholar.

The food items were identified as far as possible up to the genera.

Food Analysis

(a) Distribution of food items in the stomachs of S. leptolepis at different centres during different months.

Since the material for examination was available from different centres, the work was so planned as to facilitate a comparative study of the food of the fish in the different localities.

Tables I, II and III represent the distribution of various food items in the stomachs of *S. leptolepis* from Pudumadam, Rameswaram Road and Rameswaram respectively.

In 1957 the specimens for examination from Pudumadam (Table I) were available during May, June, September, November and December. Crustaceans formed the main item of the food—*Acetes*, *Lucifer* and *Acartia* being the most important among them.

Molluscan larvæ and shells contributed a little share to the food of the fish.

Fishes (*Anchoviella*) were next in importance to crustaceans and were common in May, June, November and December.

A certain amount of plant material, *viz.*, filamentous algæ (*Hypnea*, *Sarconema* and *Enteromorpha*) and diatoms (*Coscinodiscus*, *Navicula* and *Leptocylindrus*) was also recorded in some months.

During 1958, the material was available in all the months except October. *Lucifer* occurred from January to March, May, August, November and December in different proportions with the peak in March. A comparison of May 1957 and 1958 shows that *Lucifer* formed a very low percentage of food in 1958, whereas they remained almost at the same level in December of each year. Mysids were recorded during February, March, June and July with the maximum of 20% in February. *Acetes* was an important item of food throughout the year with the exception of March and August. In September of 1957 and 1958 it formed the entire food of the fish and recorded an increase in June, November and December 1958 over 1957. *Acartia* occurred in March and May, its proportion being greater in May 1958. Copepod eggs were observed in August only. *Euterpina*, *Oithona* and decapod larvæ were of minor importance.

Molluscan larvæ and shells occurred in March and December and formed a negligible portion of the food. Pteropods were present in March and August.

TABLE I

Percentage of different food items in the stomach contents during different months—Pudumadam

	1957								1958			
	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April
No. of fish examined ..	40	10	..	..	11	..	16	16	10	12	53	47
Lucifer ..	46·06	..	..	..	..	..	..	28·76	21·50	25·40	56·00	..
Mysids ..	..	22·40	..	..	..	..	8·00	2·70	..	20·00	2·88	..
Acetes ..	0·56	6·40	..	..	100·00	..	26·50	34·52	41·00	25·60	8·62	..
Acartia ..	14·85	42·20	..	..	..	..	40·00	..	..	..	16·16	..
Euterpina ..	..	..	..	..	..	..	2·00	..	..	..	0·43	..
Oithona ..	..	..	..	..	..	..	..	..	..	..	0·43	..
Decapod larvæ ..	0·25	..	..	..	..	..	0·50	..	..	1·00	0·50	..
Copepod eggs ..	..	..	..	..	..	..	..	..	..	..	..	..
Pteropod shells ..	..	..	..	..	..	..	..	..	..	..	4·31	..
Molluscan larvæ ..	11·22	1·20	..	..	..	..	6·00	4·32	..	..	1·28	..
Fishes ..	18·25	12·50	..	..	..	..	10·00	16·74	31·50	18·00	4·16	80·00
Alcyonarian spicules ..	..	..	..	..	..	..	..	..	..	..	0·43	..
Foraminiferan shells ..	3·00	0·70	..	..	..	..	3·00	..	2·09	2·00	0·64	..
Algæ ..	5·25	5·00	..	..	..	..	..	..	..	..	3·04	..
Diatoms ..	..	..	..	..	..	..	2·00	..	..	2·00	..	..
Sand grains ..	0·56	9·60	..	..	..	..	2·00	12·96	4·00	6·00	1·12	20·00

	1958								1959			
	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April
No. of fish examined ..	14	13	30	25	7	..	28	24	12	57	40	..
Lucifer ..	1·30	..	..	34·90	..	..	30·10	28·05	78·61	29·81	57·72	..
Mysids ..	..	6·40	3·60	..	..	..	..	..	4·65	21·86	6·17	..
Acetes ..	..	88·20	83·00	7·90	100·00	..	39·80	59·73	13·95	3·74	2·82	..
Acartia ..	61·	..	..	..	..	..	..	..	..	0·12	15·30	..
Euterpina ..	..	..	..	..	..	..	..	3·41	..	0·37	..	..
Oithona ..	..	..	..	..	..	..	..	..	..	..	..	..
Decapod larvæ ..	..	..	..	..	..	..	..	1·25	..	..	0·94	..
Copepod eggs ..	..	..	..	6·50	..	..	..	..	..	..	..	..
Pteropod shells ..	..	..	..	11·90	..	..	..	..	..	..	..	..
Molluscan larvæ ..	..	..	..	..	..	..	..	0·73	..	..	..	..
Fishes ..	7·90	..	9·80	38·80	..	..	30·10	0·73	0·93	44·10	15·84	..
Alcyonarian spicules ..	..	..	..	..	..	..	..	..	..	..	..	..
Foraminiferan shells ..	..	..	..	..	..	..	..	..	..	..	0·13	..
Algæ ..	..	..	..	..	..	..	..	0·73	1·86	..	0·94	..
Diatoms ..	..	..	..	..	..	..	..	..	..	..	0·13	..
Sand grains ..	29·50	5·40	3·60	..	..	..	..	5·37	..	..	..	..

Juveniles of *Anchoviella* formed the major item of the food during January to May, July to August, and November to December.

Filamentous algæ were noticed in March and December, and diatoms in February.

Foraminiferan shells and sand grains were of minor importance.

In 1959 fish were examined in January, February and March. Attempts were made to collect the fish in April also but without any success.

Lucifer occurred in greater proportion in January and February 1959 as compared to 1958 and was almost at the same level in March of each year. Mysids did not show any appreciable increase in February 1959 as compared to February 1958, but an increase was recorded in March 1959. *Acetes* occurred in lesser amount in the food as compared to 1958. *Acartia* was noticed in a negligible quantity in February but was more or less at the same level in March 1958 and 1959. *Euterpina* and decapod larvæ were much less common in the food as compared to other items.

Fishes showed a decrease in January and increase in February and March when compared to the same months in 1958.

Filamentous algæ were recorded in January and March and diatoms in March only.

Table II indicates the distribution of various food items in the stomachs of the fish at Rameswaram Road. Fishes were available during December 1957, February to April and December 1958 and January to April 1959.

In December 1957 when only six specimens were available for examination, Mysids, molluscan larvæ, fishes, Alcyonarian spicules, foraminiferan shells, algæ and sand grains were recorded.

In 1958, *Lucifer* was present throughout, the minimum in February and the maximum in March. Mysids and *Acetes* occurred in February and April, the latter was also recorded in December. Of the other crustaceans, *Acartia* was the most favoured item in March.

Molluscan larvæ showed a considerable decline in December when compared to the same month in 1957.

Fishes occurred in all the four months showing an increase in December 1958 over 1957.

Alcyonarian spicules, foraminifera, and sand grains were of minor importance. Filamentous algæ and diatoms were somewhat prominent the former in February and March and the latter in February only.

TABLE II

Percentage of different food items in the stomach contents during different months—Rameswaram Road

	1957	1958											1959			
	Dec.	Jan.	Feb.	March.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	Apr.
	6	..	36	20	22	..	..	..	..	..	..	..	41	4	72	32	20
Lucifer ..	..	..	4·80	77·28	72·09	..	..	..	..	..	..	..	26·65	63·75	24·32	72·41	21·64
Mysids ..	27·5	..	14·00	..	7·44	..	..	..	..	..	..	..	..	20·00	30·27	6·85	16·06
Acetes ..	..	..	48·57	..	3·46	..	..	..	..	..	..	..	59·24	2·50	15·77	0·37	0·98
Acartia ..	..	..	..	5·10	..	..	..	..	..	..	..	..	..	..	..	..	..
Euterpina ..	..	..	..	2·00	..	..	..	..	..	..	..	..	..	..	..	..	..
Oithona ..	..	..	..	3·20	..	..	..	..	..	..	..	..	..	..	..	..	..
Decapod larvæ ..	..	..	0·23	..	..	..	..	..	..	..	..	..	..	..	0·16	..	0·33
Copepod eggs ..	..	..	..	..	..	..	..	..	..	..	..	..	..	7·50	..	..	..
Pteropod shells ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4·22	..	..
Molluscan larvæ ..	20·50	..	..	0·57	..	..	..	..	..		..	..	1·70	..	0·24	..	0·33
Fishes ..	7·50	..	20·40	8·00	17·01	..	..	..	..	..	..	..	10·01	6·25	25·02	15·37	60·66
Alcyonarian spicules ..	2·50	..	..	0·57	..	..	..	..	..	..	..	..	..	..	..	..	..
Foraminiferan shells ..	2·00	..	1·40	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Algæ ..	2·50	..	4·40	2·30	..	..	..	..	..	..	..	..	..	..	..	..	..
Diatoms ..	..	..	1·30	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Sand grains ..	37·50	..	4·90	0·41	..	..	..	..	..	..	..	..	2·40	..	..	5·00	..

In 1959 *Lucifer*, Mysids, *Acetes* and fishes were common in all the months. Of these *Lucifer* was most common in January and March, Mysids in February and fishes in April.

A comparison with 1958 reveals that fall of *Lucifer* in February 1958 is compensated by the increase of *Acetes* in that month and increase in fish diet compensates the fall of *Lucifer* in April 1959.

Decapod and molluscan larvæ were negligible in the diet. Pteropod shells occurred in February only.

Food analysis of specimens collected from Rameswaram is presented in Table III. Due to irregular timings and fluctuations in fishery, it was not possible to collect the fishes in all the months. Hence, examination of fish was possible only during June, July and August in 1957 and May and September in 1958.

Lucifer was less common in June and July 1957 and May 1958, Mysids were recorded only in August 1957 and May 1958 whereas *Acetes* occurred in June, July and August 1957. *Acartia* occurred in fairly a good percentage in all the months except September 1958 when it was totally absent. Of the other crustaceans, *Euterpina*, *Oithona* and decapod larvæ were of greater importance than *Centropages*, *Pseudodiaptomus*, *Corycæus* and cypris larvæ.

Pteropod shells formed 41·40% of the food in September 1958, the highest ever recorded from any other place during the course of this investigation. Molluscan larvæ were common during June and July 1957 and May 1958.

Fishes occurred in all the months maximum being in September 1958.

Examination of fishes from Thangachimadam did not reveal the presence of any food item except for a few scales.

(*b*) *Occurrence of food organisms in different size-groups.*—A total of 830 fish was examined from Pudumadam, Rameswaram Road and Rameswaram. Fish examined from Thangachimadam are not included in this analysis since the stomachs were invariably empty except for a few scales. A sample of 50 fish was procured from Madras (East Coast) and another of 18 from Vizhingam (West Coast) for a comparative study of the food.

Specimens less than 5·0 cm. were rare in the catches and hence the food of smaller individuals could not be examined. A single specimen, 4·5 cm. in length, was collected from the shore-seine catches and attempt to collect more individuals under light fishing also proved futile.

TABLE III

Percentage of different food items in the stomach contents during different months– Rameswaram

	1957							1958								
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	Apr.	May	June	July	Aug.	Sept.
No. of fish examined .	44	14	15	..	..	..	..	..	..	..	..	31	..	..	..	8
Lucifer ..	2·12	4·00	..	..	..	..	..	..	..	..	..	0·42	..	..	..	50·00
Mysids ..	..	..	8·20	..	..	..	..	..	..	..	..	0·84	..	..	..	..
Acetes ..	1·88	9·68	81·02	..	..	..	..	..	..	..	..	..	..	..	..	..
Acartia ..	46·00	39·60	8·40	..	..	..	..	..	..	..	..	55·58	..	..	..	..
Euterpina ..	4·12	5·41	..	..	..	..	..	..	..	..	..	5·05	..	..	..	..
Oithona ..	2·75	7·56	..	..	..	..	..	..	..	..	..	16·63	..	..	..	..
Decapod larvæ ..	27·38	5·00	..	..	..	..	..	..	..	..	..	1·89	..	..	..	..
Centropages ..	2·00	..	..	..	..	..	..	..	..	..	..	0·84	..	..	..	..
Pseudodiaptomus ..	0·25	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Corycæus ..	0·37	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Cypris larvæ ..	..	..	..	..	..	..	..	..	..	..	..	0·84	..	..	..	..
Pteropod shells ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	41·40
Molluscan larvæ ..	7·50	15·37	..	..	..	..	..	..	..	..	..	10·53	..	..	..	..
Fishes ..	2·75	3·26	2·04	..	..	..	..	..	..	..	..	4·21	..	..	..	8·60
Foraminiferan shells ..	0·12	0·54	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Sand grains ..	0·50	2·00	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Diatoms ..	0·25	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Aglæ ..	2·00	7·58	0·34	..	..	..	..	..	..	..	..	3·16	..	..	..	..

Fishes were grouped at 1 cm. interval. The percentage occurrence of different items of food in various size-groups is given in Table IV. The relative importance of the items is represented graphically in Figs. 1–2. *Lucifer* was not recorded from 4·1 to 6·0 cm. but occurred in all other sizes. Mysids were restricted from 7·1 to 15·0 groups. *Acetes*, like *Lucifer*, occurred in all the sizes above 6·0 cm. *Acartia* was recorded in all the sizes except 14·1 to 15·0 cm., its occurrence being much more common in the younger individuals than in the older ones. *Euterpina* and *Oithona* were of common occurrence from the young to 11·0 cm., the former also occurring in a very low percentage in 12·1 to 13·0 cm. Decapod larvæ were recorded from all the groups. *Centropages*, *Pseudodiaptomus*, *Corycœus* and cypris larvæ were of rare occurrence in the smaller individuals. They were completely absent in the older ones. Copepod eggs were noticed from 9·1 to 14·0 cm.

Molluscan larvæ (*Pteria*) and shells were recorded from all the sizes except the last group whereas Pteropod shells occurred from 9·1 to 14·0 cm.

Fishes and fish scales were recorded from all the groups except 4·1 to 5·0 cm. They, like *Lucifer*, reached their maximum in 13·1 to 14·0 cm.

Foraminiferan shells were maximum in 7·1 to 8·0 cm. while Alcyonarian spicules in 10·1 to 11·0 cm.

Of the filamentous algæ (*Hypnea*, *Sarconema* and *Enteromorpha*) and diatoms (*Coscinodiscus*, *Rhabdonema*, *Navicula* and *Leptocylindrus*) the former occurred more frequently than the latter.

(*c*) *Relation with the plankton.*—Qualitative analysis of the plankton collected from the Gulf of Mannar at fortnightly intervals was made and the results are summarized below:

Lucifer.—They were common during the months of May, June, September, November and December 1957 but less common in July and August. In 1958, they were common during March to June, November to December but showed a decline in the months of January, February, July and September. During January to April 1959, a similar picture to 1958 was observed.

Acartia.—From May 1957 it was common in the collections with the exception of September and October and showed somewhat similar trend in 1958. It was also common from January to April 1959.

Decapod larvæ.—They were less common during the months of September and October 1957 and July and October 1958 as compared to the rest of the months.

TABLE IV*

Percentage occurrence of different food items in various size-groups

Size-groups (cm.)	No. of fish examined	*Lucifer*	Mysids	*Acetes*	*Acartia*	*Eurterpina*	*Oithona*	Decapod larvæ	*Centropages*	*Pseudo-diaptomus*	*Corycæus*
4·1– 5·0	1	..	..	..	100·00 (1)	100·00 (1)	100·00 (1)	100·00 (1)	..	..	..
5·1– 6·0	13	..	..	..	100·00 (13)	69·23 (9)	53·85 (7)	76·92 (10)	7·70 (1)	7·70 (1)	7·70 (1)
6·1– 7·0	45	15·56 (7)	..	15·56 (7)	95·56 (43)	55·56 (25)	51·11 (23)	66·67 (30)	22·22 (10)	4·44 (2)	4·44 (2)
7·1– 8·0	37	16·22 (6)	16·22 (6)	27·03 (10)	72·97 (27)	32·43 (12)	24·32 (9)	43·24 (16)	..	..	..
8·1– 9·0	55	25·45 (14)	3·64 (2)	60·00 (33)	18·18 (10)	10·91 (6)	5·45 (3)	9·09 (5)	..	..	..
9·1–10·0	83	45·78 (38)	19·28 (16)	60·24 (50)	28·92 (24)	6·02 (5)	2·41 (2)	10·84 (9)	..	..	..
10·1–11·0	179	64·80 (116)	27·37 (49)	28·49 (51)	18·99 (34)	2·79 (5)	1·68 (3)	5·59 (10)	..	..	..
11·1–12·0	186	65·59 (122)	31·18 (58)	32·80 (61)	8·60 (16)	..	..	4·84 (9)	..	..	..
12·1–13·0	155	65·81 (102)	61·94 (96)	54·19 (84)	2·58 (4)	0·64 (1)	..	5·81 (9)	..	..	..
13·1–14·0	71	66·20 (47)	50·70 (36)	50·70 (36)	5·63 (4)	..	..	5·63 (4)	..	..	..
14·1–15·0	5	60·00 (3)	40·00 (2)	40·00 (2)	..	..	..	20·00 (1)	..	..	..

TABLE IV*—(*Contd.*)

Size-groups (cm.)	No. of fish examined	Cypris larvæ	Copepod eggs	Pteropod shells	Molluscan larvæ	Fishes	Alcyonarian spicules	Foraminiferan shells	Algæ	Diatoms
4·1– 5·0	1	..	..	..	100·00 (1)	..	..	..	..	..
5·1– 6·0	13	7·70 (1)	..	..	84·62 (11)	15·38 (2)	..	..	15·38 (2)	..
6·1– 7·0	45	4·44 (2)	..	..	80·00 (36)	22·22 (10)	..	4·44 (2)	13·33 (6)	8·89 (4)
7·1– 8·0	37	2·70 (1)	..	..	59·46 (22)	29·73 (11)	..	13·51 (5)	13·51 (5)	5·40 (2)
8·1– 9·0	55	..	..	..	14·54 (8)	29·09 (16)	..	5·45 (3)	9·09 (5)	.
9·1–10·0	83	..	6·02 (5)	8·43 (7)	26·51 (22)	43·37 (36)	..	8·43 (7)	19·28 (16)	1·20 (1)
10·1–11·0	179	..	7·82 (14)	13·41 (24)	12·29 (22)	59·78 (107)	1·68 (3)	4·47 (8)	6·14 (11)	1·68 (3)
11·1–12·0	186	..	1·61 (3)	5·91 (11)	9·14 (17)	62·90 (117)	1·61 (3)	3·76 (7)	10·22 (19)	0·54 (1)
12·1–13·0	155	..	2·58 (4)	1·94 (3)	12·90 (20)	64·52 (100)	0·64 (1)	8·39 (13)	20·64 (32)	3·22 (5)
13·1–14·0	71	..	2·82 (2)	2·82 (2)	9·86 (7)	100·00 (71)	..	12·68 (9)	16·90 (12)	5·63 (4)
14·1–15·0	5	..	..	..	..	60·00 (3)	..	..	..	..

* Figures in brackets indicate the number of fish in which each item has occurred.

Pteropod shells.—Their occurrence was seasonal and they were common from August to November 1957, January to March, September and November 1958 and January to March 1959.

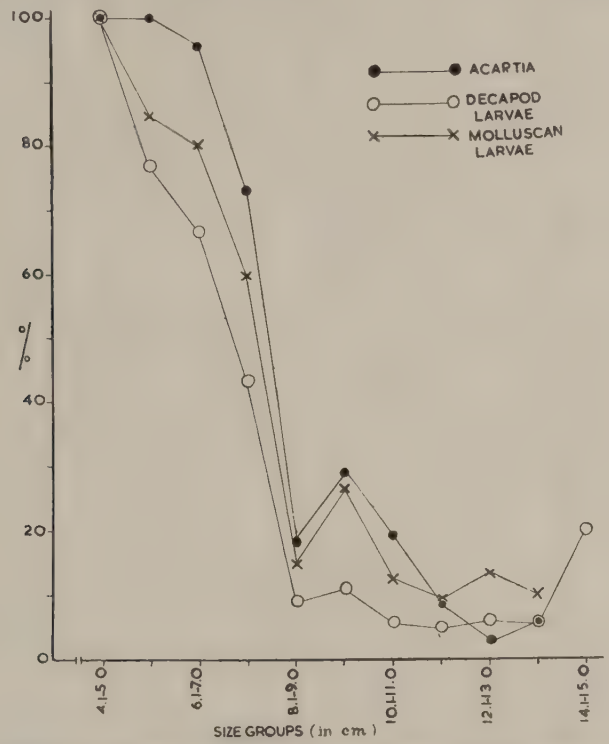


FIG. 1. Showing the relative importance of food items in various size-groups.

Molluscan larvæ.—They were common in all the months except June 1957, February, April and June 1958.

Diatoms.—They were present in all the months with the peak in October and November and sometimes plenty in December.

A comparison of Tables I to IV with the plankton observations leads to the conclusion that the occurrence and the extent of distribution of the food items in the stomachs of *S. leptolepis* have a combination with their distribution in the plankton in different months. Table IV indicates that in the lower size-groups *Acartia*, *Euterpina*, *Oithona*, decapod larvæ and molluscan larvæ constitute favourite food and as the fish grows their occurrence tends to

decrease and the fish eats more and more of *Lucifer*, *Acetes*, Mysids and fishes. Thus, as the fish grows it shows a tendency to feed on the bigger items. It is interesting to point out here that on several occasions the stomachs were noticed to have either *Lucifer* or *Acetes* or Mysids or fishes only.

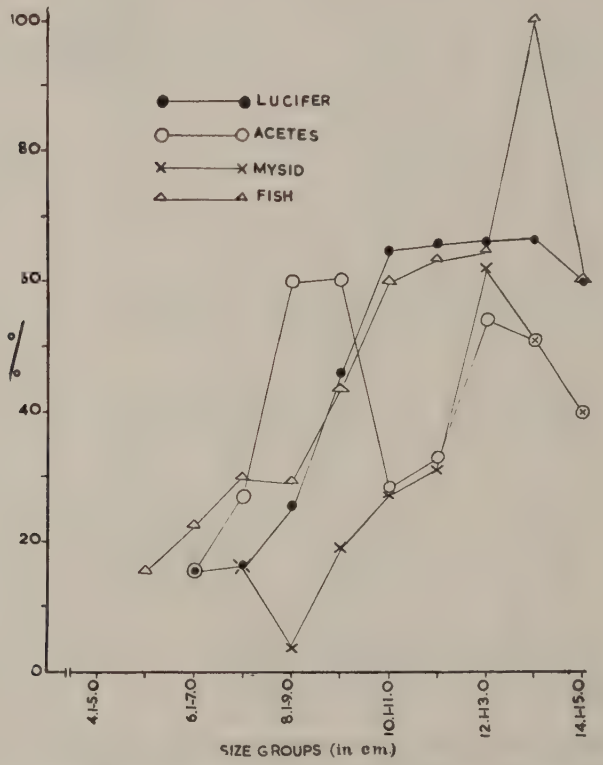


FIG. 2. Showing the relative importance of food items in various size-groups.

(*d*) *Degree of feeding.*—Table V presents the state of the stomach (in percentage) in different degrees of fullness from May 1957 to May 1959. Fishes labelled as full, $\frac{3}{4}$ full and $\frac{1}{2}$ full were considered to have fed actively while those labelled as $\frac{1}{4}$ full showed less feeding. The occurrence of empty stomachs was much less at Pudumadam, Rameswaram Road and Rameswaram, but very common at Thangachimadam. In April high percentage of empty stomachs was recorded from Pudumadam which was due to the difference in time of collection. The occurrence of $\frac{1}{4}$ full stomachs

TABLE V

State of the stomach in percentage in different degrees of fullness in various months from different centres

	1957								1958					
	May	June	July	August	Sep.	October	Nov.	Dec.	January	February	March	April	May	June
PUDUMADAM :														
Full ..	86·6	70·0	..	..	18·2	..	75·0	12·5	100·0	..	18·9	..	21·5	12·0
¾ full ..	8·4	..	..	..	27·3	..	6·3	37·5	..	..	18·9	..	7·1	24·0
½ full ..	5·0	10·0	..	..	18·2	..	12·4	12·5	..	..	37·8	2·1	42·8	8·0
¼ full ..	..	10·0	..	..	36·3	..	..	37·5	..	75·0	22·6	..	28·6	56·0
Empty ..	..	10·0	..	..	..	..	6·3	..	..	25·0	1·8	97·9*	..	..
RAMESWARAM ROAD :														
Full ..	..	..	..	..	..	..	..	..	..	100·0	..	95·5	..	..
¾ full ..	..	..	..	..	..	..	..	..	..	..	25·0	..	..	..
½ full ..	..	..	..	..	..	..	..	50·0	..	..	35·0	4·5	..	..
¼ full ..	..	..	..	..	..	..	..	50·0	..	..	40·0	..	..	..
Empty ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
RAMESWARAM :														
Full ..	..	90·9	85·8	92·6	..	..	..	..	..	..	..	..	61·3	..
¾ full ..	..	..	7·1	7·4	..	..	..	..	..	..	..	..	6·5	..
½ full ..	..	..	7·1	..	..	..	..	..	..	..	..	..	19·3	..
¼ full ..	..	..	..	..	..	..	..	..	..	..	..	..	12·9	..
Empty ..	..	9·1	..	..	..	..	..	..	..	..	..	..	..	..
THANGACHIMADAM :														
Empty* ..	100·0	100·0	100·0	100·0	100·0	100·0	..	..	..	..	100·0	100·0	100·0	100·0

TABLE V—(*Contd.*)

	1958						1959				
	July	August	September	October	November	December	January	February	March	April	May
PUDUMADAM :											
Full ..	33·3	76·0	57·1	..	58·0	70·8	75·0	45·6	82·5	..	..
¾ full ..	10·0	24·0	..	..	42·0	..	8·3	12·3	7·5	..	..
½ full ..	30·0	..	14·3	..	..	29·2	16·7	22·8	10·0	..	..
¼ full ..	20·0	..	28·6	..	..	..	..	17·5	..	..	..
Empty ..	6·7	..	..	..	..	..	..	1·8	..	..	..
RAMESWARAM ROAD:											
Full ..	..	..	..	..	..	73·2	100·0	68·0	56·3	45·0	..
¾ full ..	..	..	..	..	..	7·3	..	15·3	28·1	20·0	..
½ full ..	..	..		..	..	14·6	..	13·9	12·5	30·0	..
¼ full ..	..	..		..	..	4·9	..	2·8	3·1	5·0	..
RAMESWARAM :											
Full ..	..	..	0·0	..		..	..	..	..	..	..
THANGACHIMADAM :											
Empty* ..	100·0	100·0	100·0	100·0	100·0	..	..	..	100·0	100·0	100·0

* Fishes were caught at night.

in greater proportion in certain months in one year and much less in other at different centres in the same months may well be explained due to the difference in time of fishing.

(*e*) *Feeding in relation to sexual cycle.*—Mature fish though continue to occur throughout the year, the concentration of those individuals can be noticed only during February, March, August and September immediately followed by spent, spent recovering and juvenile stages of the fish. It can be noticed from the table for Pudumadam (Table I) that the fish collected during September 1957, and March, August and September 1958 and from January to March 1959 had fed actively during the spawning season. Similarly the table for Rameswaram Road (Table II) indicates the high degree of feeding in February and March 1958 and 1959. The observations from Rameswaram (Table III) further confirm that the fish do not stop feeding or show a sign of cessation of feeding during spawning season. Here it is worthwhile to mention that three specimens (all female) collected in the running stage in August 1958 had full stomachs containing *Lucifer*, *Acetes* and juveniles of *Anchoviella*. It can be further stated from Table IV that there is no change in the food of fish in different stages of maturity. The fish which attains a size of 10 cm. at first maturity continues to feed on the same items of food even after it has spawned. The proportions of different items, however, may vary.

Discussion

For the purpose of comparison other Carangids, *viz.*, *Caranx melampygus*, *C. sexfasciatus*, *Selar kalla* and *S. mate* were examined. Of these the last three were caught and collected at night from Mandapam and Thangachimadam. On examination they had nothing in their stomachs except for a few scales showing similar results as in *S. leptolepis*. A sample of 18 fishes of *S. leptolepis* examined from Vizhingam (West Coast) caught at night in bag-net revealed a similar picture. Another collection from bag-nets from Madras during day at 2 P.M. revealed the presence of *Lucifer* appendages, Mysids, *Acartia*, decapod larvæ, *Labidocera*, Pteropod shells, molluscan larvæ and fishes in their stomachs. The stomachs of these fishes were only $\frac{1}{4}$ full which was due to the time of catching the fish. Examination of the stomachs of *S. leptolepis* from the shore-seine collections at night from Pudumadam also did not reveal the presence of any organism but for a few scales, which is an indication that the fish had fed long ago. This explains the higher percentage of empty stomachs in April 1958 at this place. The absence of food in the stomachs of *S. leptolepis* caught at night can be due to one of two possible causes:

1. Absence of feeding activity at night.
2. Regurgitation by the fish when hauled up.

To investigate these possibilities a critical examination of the stomach contents of the fish was made from Pudumadam, Rameswaram Road and Rameswaram. Fish were taken from different hauls at different periods of the day. It was found that the fish caught in the early hours till about 8 A.M. contained little food and those caught after 8 A.M. had stomachs in different degrees of fullness. The food items were easily identifiable due to incomplete digestion. The absence of food in the stomachs was thus not due to any regurgitation but due to the difference in time of catching the fish.

It appears that the feeding behaviour of *S. leptolepis* is similar to that observed by Bhattacharyya (1957) in larval and post-larval herrings and by Qasim (1957) in *Blennius pholis* and by Hatanaka and Murakawa (1958) in *Seriola quinqueradiata.*

Caranx sexfasciatus and *C. melampygus* were collected from shore-seines during day, the former had only *Anchoviella* in their stomachs while in the latter the stomachs were full of *Leiognathus*, *Anchoviella*, *Acetes*, Mysids and *Sepia*. An interesting feature was observed in *C. sexfasciateus* which were also caught at 3 A.M. in shore-seines. Contrary to the expectations, the stomachs were full of *Sardinella*, *Ilisha* and *Anchoviella*. In one specimen in addition to these items a single specimen of *Squilla* and *Selar malam* (Carangid) were also recorded. The feeding behaviour of *C. sexfasciateus* is, thus, comparable to that observed by Soemarto (1958) in *Decapterus.*

Tham Ah Kow (1950) on the food studies of *Caranx leptolepis* from Singapore Strait concluded that the fish selectively feeds on zooplankton. The presence of zooplankton and juveniles of *Anchoviella* in major quantities and occurrence of filamentous algæ and diatoms only occasionally, as noticed during the present investigations, lead one to infer that this fish is mainly carnivorous supplementing its food with phytoplankton according to their availability. These results, thus, are contrary to the view of Tham Ah Kow (1950). In this connection it is of interest to note that the occurrence of plant material in the food of Carangids has not been mentioned by Lebour (1918, 1920), Chacko (1949), Mahadevan (1950), Datar (1954) and Vijayaraghavan (1957). However, Kuthalingam (1955 *b*) and Chacko and Mathew (1956) do refer to the occurrence of very small amount of vegetable matter in the food of Indian horse-mackerel.

SUMMARY

1. During the course of two years of investigation 830 fish of various sizes were examined from Pudumadam, Rameswaram Road and Rameswaram. The stomachs of the fish examined from Thangachimadam were invariably empty.

2. Points and Occurrence methods were followed to analyse the food contents.

3. *Acartia*, *Oithona*, *Euterpina*, decapod and molluscan larvæ are preferred in the lower groups whereas *Lucifer*, *Acetes*, Mysids and fishes in the higher ones.

4. Fish show indications of cessation of feeding during night.

5. It is mainly a carnivorous fish, occasionally feeding on phytoplankton.

I am grateful to Dr. S. Jones and Dr. R. Raghu Prasad for going through the manuscript and for their useful suggestions and constant encouragement. I am also thankful to Dr. G. Seshappa for his kind suggestions. My grateful thanks are due to the Ministry of Education, Government of India, for the award of a Senior Research Scholarship.

REFERENCES

Bhattacharyya, R. N. 1957 .. The food and feeding habits of larval and post-larval herring in the Northern North Sea. *Mar. Res*, (3), 1–15.

Chacko, P. I. 1949 .. The food and feeding habits of the fishes of the Gulf of Mannar. *Proc. Ind. Acad. Sci.*, **29 B**, 83–97.

——— and Mathew, M. J. 1956 Biology and fisheries of the horse-mackerel of the West Coast of Madras State. *Cont. Mar. Biol. St. West Hill, Malabar Coast*, (2), 1–12.

Datar, G. G. 1954. .. Food and feeding habits of *Caranx rottleri* (Cuv. and Val.). *Proc. 41st Ind. Sci. Cong. Assoc.*, (3), (Abstract), 181.

Frost, W. E. 1943 .. The natural history of minnow, *Phoxinus phoxinus*. *J. Anim. Ecol.*, **12**, 139–62.

Hatanaka, M. and Murakawa, G. 1958 Growth and food consumption in young amber fish, *Seriola quinqueradiata* (T. et S.) *Tohoku. J. Agri. Res.*, **9** (2), 69–79.

Hynes, H. B. N. 1950 .. The food of the freshwater sticklebacks (*Gastreosteus aculeatus* and *Pygosteus pungitius*) with a review of methods used in studies of the food of fishes. *J. Anim. Ecol.*, **19**, 36–58.

Kuthalingam, M. D. K. 1955 *b* The food of horse-mackerel. *Curr. Sci.*, **24**, 416–17.

Lebour, M. V. 1918 .. The food of post-larval fish. *J. Mar. biol. Ass. U.K.*, **11,** 433–69.

————. 1920 .. Food of young fish No. III. *Ibid.*, **12,** 261–324.

Mahadevan, S. 1950 .. The digestive system of *Caranx djedaba* (Forsk.) and *Trichiurus humela* (Forsk). *J. Madras Univ.*, **20,** 25–48.

Qasim, S. Z. 1957 .. The biology of *Blennuis pholis* L. (Teleostei). *Proc. Zool. Soc. Lond.*, **128,** 161–208.

Soemarto. 1958 .. Fish behaviour with special reference to Pelagic shoaling species: Lajang (*Decapterus* spp.). *Indo-Pac. Fish. Council, Sym.* 21, 1–12.

Swynnerton, G. H. and Worthington, E. B. Note on the food of fish in Haweswater (Westmorland). *J. Anim. Ecol.*, **9,** 183–87.

Tham Ah Kow. 1950 .. The food and feeding relationships of the fishes of Singapore Straits. *Colonial Off. Fish. Pub.*, **1** (1), 1–35.

Vijayaraghavan, P. 1957 .. *Studies on Fish Eggs and Larvæ.* Univ. Madras.

NOTES ON EGGS, LARVÆ AND JUVENILES OF FISHES FROM INDIAN WATERS

V. *Euthynnus affinis* (Cantor)*

By S. Jones

(*Central Marine Fisheries Research Station*)

Larval stages of *Katsuwonus pelamis* (Linnaeus) and *Neothunnus macropterus* (Temminck and Schlegel) collected mostly on board the Research Vessel *KALAVA* from the Laccadive Sea and the Gulf of Mannar were described in the previous two numbers in this series (Jones, 1959). A few small larvæ resembling those of *Euthynnus* described from the Pacific region by Wade (1951) and Matsumoto (1958 and 1959) were present in the *KALAVA* collection but the material was not adequate for fixing the identity with reasonable certainty. However, a fairly large number of juvenile and young stages of *Euthynnus affinis* were obtained from shore-seines from Vizhinjam, a fishing centre about 9 miles south of Trivandrum and from boat-seines from Calicut and these are dealt with in this account.

According to Godsil (1954) four species are recognised under the genus *Euthynnus*, viz., *E. alletteratus* from the Atlantic, *E. affinis* from the Indian Ocean and *E. yaito* and *E. lineatus* from the Pacific. Of these *E. alletteratus* is distinct from the rest, while *E. lineatus*, in spite of its external resemblance to the other two species, is considered different on account of the difference in vertebral count. On the other hand it would appear that *E. affinis* and *E. yaito* constitute a widely distributed single species in the Indo-Pacific. This aspect is being dealt with elsewhere and if this view is confirmed the specific name *affinis* will have priority over *yaito*. In the present account for the sake of convenience *E. affinis* is treated separately but the stages are compared with the corresponding stages of *E. yaito*.

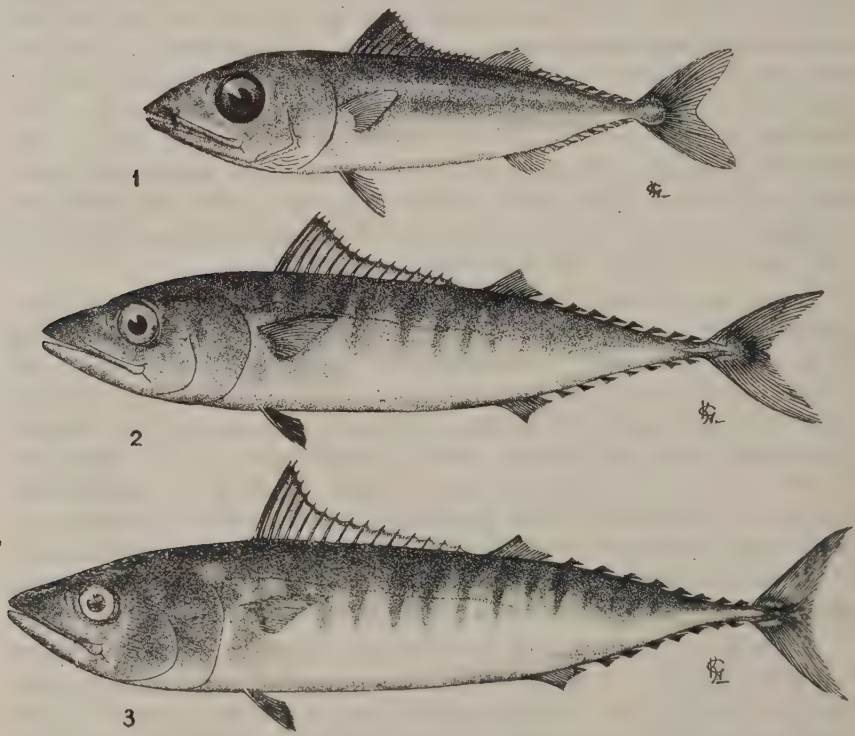
There is no information on the embryonic or larval stages of *E. affinis* from Indian waters. Delsman (1926) described some eggs and early larvæ from the Java Sea under the presumption that they were of *Scomber kanagurta* but subsequently he adduced reasons (Delsman, 1931) to show that they were actually of *E. affinis*. If his inference is correct eggs of this species have a diameter of 0·85–0·95 mm. with an oil globule of about 0·21–0·24 mm. The newly hatched larva measures about 2·05 mm.

---

* *Thynnus thunnina*, Cuvier and Valenciennes of Day (1878).

There are in all 82 specimens measuring from 24·5 mm. to 321·5 mm. Of these 54 specimens are below 75.00 mm., all of which are from Vizhinjam except three which are from Calicut. Of the remaining larger specimens only five are from Vizhinjam and the rest are from Calicut. Particulars about a selected number of specimens from these are given in Table I.

24·5 *mm.* (Fig. 1).—This is the smallest specimen in the collection and has a total length of 29·5 mm. It was obtained from Vizhinjam on 29–5–1958. The eyes are large and conspicuous and the mouth has small teeth. All the larval characters are lost except the vestiges of the preopercular spines. Lateral line is not distinct. The general colour is brown dorsally gradually becoming white below.



FIGS. 1–3. *Euthynnus affinis* (Cantor). Fig. 1. 24·5 mm. Fig. 2. 56·6 mm. Fig. 3. 96·0 mm. (by Mr. K. G. Nambiar).

The resemblance of this to the 33·5 mm. *E. yaito* described by Wade (1950) from the Philippine waters is striking while it looks distinctly

TABLE I

Measurements of Euthynnus affinis (*Cantor*) *in mm.*

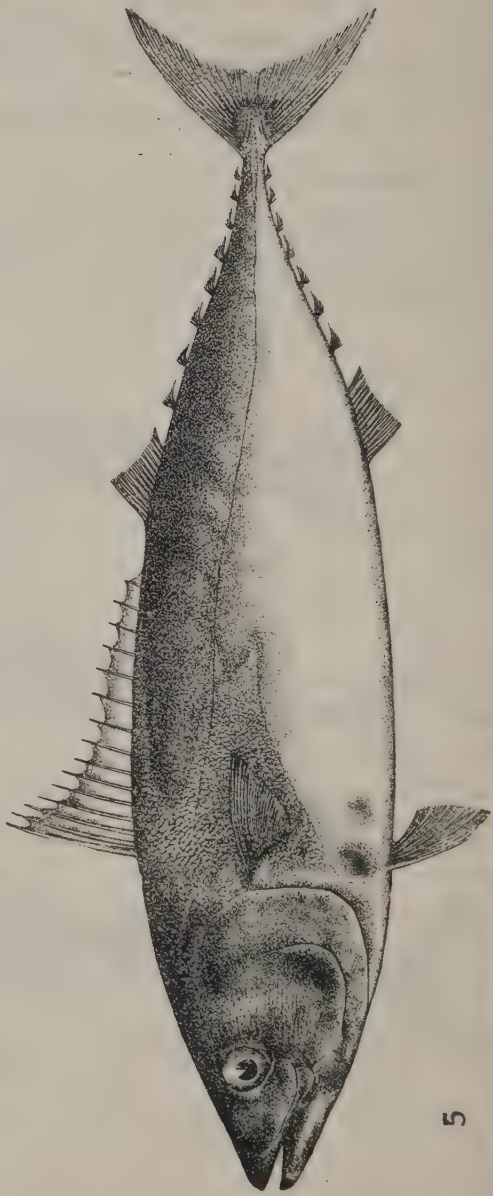
Sl. No.	Place and date	Standard length	Head	Snout	Eye	Maxilla	Depth (max.)	Sn. to Ist D.	Ist dorsal sp ne	Gill raker count
1*	†V. 29—5—1958	24·5	9·65	3·6	2·4	5·2	6·1	10·4	3·4	?
2	V. Jan. 1957	34·3	11·7	4·1	3·2	6·3	7·8	13·0	3·9	5+15
3	V. 24—1—1957	38·6	13·2	4·7	3·3	6·9	8·6	14·9	4·2	5+18
4	V. 29—5—1958	40·6	13·5	4·6	3·1	7·0	9·0	14·8	4·1	5+17
13	V. Jan. 1957	45·5	14·1	5·0	3·6	7·4	9·9	16·2	5·3	6+21
18	V. Jan. 1957	50·0	15·8	5·3	3·8	8·1	10·7	17·2	6·2	6+21
25*	V. 24—1—1957	56·6	17·5	6·0	4·0	8·8	11·8	20·0	6·3	7+23
32	V. Jan. 1957	60·5	18·0	6·0	4·2	9·1	13·1	21·3	6·8	7+22
37	V. Jan. 1957	65·0	20·0	6·7	4·2	10·0	14·2	23·3	7·7	7+23
52	‡C. 25—9—1956	72·0	20·9	7·1	4·6	10·0	14·9	24·2	8·2	8+23
55	V. Jan. 1957	75·0	22·2	7·6	4·7	11·0	15·0	25·6	9·1	8+23
56	C 25—9—1956	85·0	24·9	8·6	5·0	12·0	17·0	29·0	9·3	8+23
59	C. 25—9—1956	88·5	25·8	8·4	5·1	12·2	17·5	29·1	9·5	8+23
60	C. 25—9—1956	90·8	25·7	8·4	5·1	12·1	17·5	29·2	10·1	8+24
65*	V. 3—6—1958	96·0	28·0	9·3	5·2	13·0	19·0	31·4	11·2	8+23
67	V. 15—10—1956	116·5	33·7	11·0	6·2	15·4	26·9	38·2	14·5	8+24
68	C. 25—9—1956	137·5	37·5	12·1	6·5	17·0	29·0	42·6	17·7	8+24
69	C. 25—9—1956	140·0	38·7	12·2	6·7	16·8	30·1	43·7	17·4	8+24
70*	V. 10—11—1256	162·0	42·2	13·0	7·1	18·8	35·0	50·4	18·8	8+25
71	C. 14—9—1956	209·5	56·0	18·2	10·5	25·0	45·0	65·5	26·0	8+19
72*	C. 14—9—1956	222·0	62·5	21·0	9·8	26·3	53·5	72·5	27·6	9+23
75	C. 14—9—1956	231·0	65·0	20·5	11·2	27·3	55·0	75·5	31·0	9+21
76	C. 14—9—1956	237·0	66·5	19·8	11·3	28·0	51·5	76·3	30·5	9+21
77	C. 15—9—1956	242·5	66·5	21·5	11·5	29·0	57·0	77·5	32·0	9+21
78	C. 27—7—1956	246·5	66·5	21·0	11·3	29·0	56·5	78·0	32·3	9+21
79	C. 25—9—1956	265·0	73·0	22·8	12·2	31·2	66·5	86·5	35·0	9+22
81	V. 29—5—1958	281·0	78·5	24·8	12·3	32·6	70·0	91·0	36·5	9+23
82	V. 29—5—1958	321·5	89·5	27·0	15·0	37·5	80·5	100·5	44·5	9+22

* Denotes specimens described and figured.

† V = Vizhinjam.

‡ C = Calicut.

4



5

FIGS. 4–5. *Euthynnus affinis* (Cantor). Fig. 4. 162·0 mm. (by Mr. K. G. Nambiar). Fig. 5. 222·0 mm. (by Mr. K. L. K. Kesavan).

different from the 26 mm. *E. alletteratus* described by Matsumoto (1959) from the Gulf of Mexico.

56·6 *mm.* (Fig. 2).—This specimen was collected from Vizhinjam on 24–1–1957 and has a total length of 66 mm. Its body proportions and other details are given in Table I. The eyes are comparatively smaller and the body is more elongated than in the previous stage. The lateral line is distinct in the anterior region. The caudal peduncle bears a keel on each side. The general colour of the body is brown but there are dark bands which are broad at the dorsal aspect but taper and disappear as they come down to the sides.

In general appearance it is very much like the 67 mm. *E. yaito* described by Wade (1950) from Philippine waters.

96 *mm.* (Fig. 3).—This was collected from Vizhinjam on 3–6–1958 and has a total length of 106 mm. The general colour is somewhat deeper than in the previous stage and the bands, of which 13 on each side could be distinguished, are more distinct. The lateral line is complete and corselet scales have developed at the base of the pectoral fins.

162 *mm.* (Fig. 4).—This was collected from Calicut on 10–11–1956 and has a total length of 179 mm. Except for the rather elongated appearance of the body most of the external features of the adult are present at this stage. The corselet of scales have developed but they extend to only up to the vertical to the 9th dorsal spine on each side. Oblique irregular bands are present on the dorsal aspect above the lateral line but these have not resolved into the distinct patterns as in the adult. Two diffuse dark areas on either side between the pectoral and pelvic fins evidently indicate the position of the so-called thumb impressions or blotches in the adult.

222 *mm.* (Fig. 5).—This young fish was collected from Calicut on 14–9–1956 and has a total length of 248 mm. It has all the unmistakable features of the adult except for the characteristic colour pattern between the dorsal fin and the lateral lines. The blotches below the pectorals are clear though not so intense as in the adult.

Specimens larger than the above in the collection are being dealt with elsewhere. The fish grows to a length of about 75 cm. and is the commonest thunnid on the coasts of the mainland of India and forms a fishery of appreciable importance during certain seasons.

My thanks are due to my colleagues, Dr. V. Balakrishnan and Mr. K. V. Narayana Rao for the specimens from Vizhinjam and to Messrs. M. Kumaran and Egbert Dawson for the assistance given in the laboratory.

REFERENCES

Day, F. 1878 .. *The Fishes of India*, London.

Delsman, H. C. 1926 .. Fish eggs and larvæ from the Java Sea. 9, *Scomber kanagurta* C. V. *Treubia*, **8**. 395–99.

————. 1931 .. Fish eggs and larvæ from the Java Sea. 18. The genus *Cybium*. *Ibid.*, **13**, 401–10.

Godsil, H. C. 1954 .. A descriptive study of certain tuna-like fishes. *California Division Fish and Game, Fish. Bull.*, **97**, 1–185.

Jones, S. 1959 .. Notes on eggs, larvæ and juveniles of fishes from Indian waters. III. *Katsuwonus pelamis* (Linnaeus) and IV. *Neothunnus macropterus* (Temminck and Schlegel). *Indian J. Fish.*, **6** (2), 360–73.

Matsumoto, Walter, M. 1958 Description and distribution of larvæ of four species of tuna in Central Pacific waters. *U.S. Fish and Wildlife Service, Fish. Bull.*, **128**, 31–72.

————. 1959 .. Descriptions of *Euthynnus* and *Auxis* larvæ from the Pacific and Atlantic Oceans and adjacent seas. *Dana Report*, **50**, 1–28.

Wade, Charles, B. 1950 .. Juvenile forms of *Neothunnus macropterus*, *Katsuwonus pelamis* and *Euthynnus yaito* from Philippine seas. *U.S. Fish and Wildlife Service, Fish. Bull.*, **53**, 395–404.

————. 1951 .. Larvae of tuna and tuna-lake fishes from Philippine waters. *Ibid.*, **57**, 445–485.

NS ON POLLUTION OF THE BY THE EFFLUENTS OF A)RY, BALRAMPUR (U.P.)

ANERJEA AND M. P. MOTWANI

and Fisheries Research Station)

INTRODUCTION

ı was first in the series, Motwani *et al.* (1956) ' the problem of pollution in India and they disposal problem must be pursued with due of fishery resources of our national waterways. gar factories have waste materials which if ı do much to alter the physical, chemical and :eiving waters. Washings from sugarcane, ıe-cake slurry, molasses and oil from machi- ommon types of wastes from a sugar factory er of inorganic and organic compounds some ıbstances by decomposition and others which :ural regimen of the conditions of existence.

to pollution of the Suvaon stream by effluents ı the district of Gonda of Uttar Pradesh, was ason in December 1954, following the reports of Animal Husbandry, Uttar Pradesh, that Balrampur are adversely affected by sugar wastes discharged into it and that heavy fish mortality has become an annual feature in the 2-mile stretch of the Suvaon below the outfall. The chemical and biological observations made in the 11-mile sector of the river were continued up to 1959 and form the basis of the present communication.

II. FACTORY PROCESS WITH NATURE AND COMPOSITION OF WASTES

The Balrampur Sugar Factory located near the Railway Station along the highway to Gonda, manufactures white crystalline sugar from sugarcane by double sulphitation process in which raw juices extracted from cane are treated with lime and then with sulphur dioxide to eliminate various unwanted ingredients and colouring matters. The treated juice is passed through filter presses and clear solution is then boiled to thickness in vacuum

evaporators with graining completed in vacuum pans. The resultant material commercially known as "massecuite" is cured by centrifugal machines whereby sugar is separated from molasses which pass out as effluent to be subsequently treated in vacuum pans for extraction of extra sugar and the waste molasses are then stored in tanks for disposal to companies manufacturing power alcohol. On some occasions when storage facilities become limited the waste molasses are thrown into the stream as effluent.

On an average the factory crushes 5,600 tons of cane per week yielding about 500 tons of crystalline sugar and 210 tons of molasses as by-product. Pertinent to this factory, details of information, as to plant operation, source of water-supply, quantity and types of raw materials and chemicals used with volume of wastes and nature of their disposal, are given in Appendix 'A'.

The liquid wastes calculated to be 7,80,000 gallons per day of operation contain among others soil, variable quantities of cane fibres and cellulose, lime, waxes, fermented sugar juices, molasses and some quantities of sulphate and phosphate of calcium, lactic acid and oils from machineries. Table I gives summarised results of the chemical analysis of the effluent before its discharge into the stream.

TABLE I

Physico-chemical conditions of the effluent

Item	Value	Item	Value
Turbidity	240–300 p.p.m.	Nitrate (as NO_3—N)	0·06–0·07 p.p.m.
pH	6·6–6·7	Phosphate (as P_2O_5)	0·62–0·88 p.p.m.
D.O.	Nil	O.C.	420–630 p.p.m.
CO_2	48–60 p.p.m.	B.O.D.	800–920 p.p.m.
CO_3	Nil	Colour	Black
HCO_3	230–260 p.p.m.	Odour	Organic (H_2S)

It is seen from Table I that the wastes are predominantly organic in composition with very high B.O.D. and O.C. (permanganate test) values and complete absence of dissolved oxygen. The wastes, slightly acidic in nature, contain quantities of sugar which favour the growth and development of sulphur-reducing bacteria producing hydrogen sulphide accompanied by strong offensive odour.

Short period bio-assay experiments were conducted in the field laboratory with freshly collected effluent. The test fish used in the experiments were *Puntius ticto* and *Oxygaster bacaila* collected from the freshwater zone of the Suvaon and acclimatised for 24 hours in the environmental water with dissolved oxygen maintained at 4·0 to 6·0 p.p.m. A logarithmic dilution ratios from 1 : 1 to 1 : 100 were used in the preliminary series and later more convergent dilution ratios were considered to determine the exact dilution which would render the effluent innocuous to fish. Two series of experiments were run of which in one the effluent was used as such and in the other optimal level of respiratory oxygen was maintained artificially. It was observed that without aeration the effluent was harmless at a dilution ratio of 1 : 0·9 but with aeration no detrimental or toxic effect was apparent at a dilution of 1 : 0·5. This clearly shows that the pollutional effect of the effluent is only of secondary nature. The effluent does not contain any constituents which might be directly toxic to aquatic life. The high oxygen demand of the effluent, however, depletes it totally of dissolved oxygen and fish cannot survive in it. The toxic condition in the stream is produced by the decomposition of chemical compounds like sulphates to hydrogen sulphide in the anaerobic condition and low red-ox potential created by the highly organic effluent.

III. Stream Survey

The Suvaon, which is a small monsoon-fed stream, originates in the district of Baraich in Uttar Pradesh and after meandering through the plains it joins Rapti, a tributary of the Ganga River, at two points—one through Chandatal and the other near the border of Gonda and Basti Districts. The main flow, however, is towards Chandatal which is a fairly large lake at a distance of about 10 miles south of Balrampur. The continuity of the Suvaon with the Rapti is established through Chandatal only during the monsoon months of June to August, and once the monsoon floods recede, the Suvaon and Chandatal get disconnected from the parent river and the Suvaon assumes characteristics of a land-locked channel with virtually no flow from October to May, and the water becomes stagnant. Since the stream-water is also utilised by riparian cultivators specially during the winter and the summer months, the level of water registers a progressive fall and during the period of our observations, the channel was hardly 3 to 4 feet deep along greater part of its length except in some places where deep and wide pools existed. The average volume of discharge during the crushing season was determined to be about 0·5 to 1·0 cusecs.

Four field surveys during the cane crushing season were conducted in different years of observations. In the eastern districts of Uttar Pradesh crushing season generally commences from late November and continues up to March, and during this period the river flow was observed to be very low although not the lowest as obtained during the late summer months. Observations as to physico-chemical conditions, species composition and relative abundance of fish fauna, plankton and bottom biota were made at each of the ten sampling stations in the 11-mile stretch of the Suvaon from railway bridge to Sunde bag near Chandatal (Fig. 1). Sampling stations I to III were situated in the clear water zone above the effluent confluence and the other seven were located at various distances downstream as shown below.

Number of station	Location	Distance from Station I
		(miles)
I	Above railway bridge	0·0
II	Between railway and road bridges	1·0
III	Above confluence of outfall	2·0
IV	Below the outfall	3·0
V	Nahar bridge	4·0
VI	Near Jhanjari village	6·0
VII	Below Jhanjari	7·0
VIII	Above Banjari village	8·0
IX	At Banjari	10·0
X	Near Sunderbag	11·0

(i) Physico-Chemical Conditions

The physico-chemical factors examined were: water temperature, turbidity, colour, odour, pH, dissolved oxygen, total alkalinity, 5-day B.O.D. and oxygen consumed from permanganate. For methods of collection and chemical analysis of samples, standard methods of A.P.H.A. (1946) were followed. Table II gives summarised physico-chemical conditions of

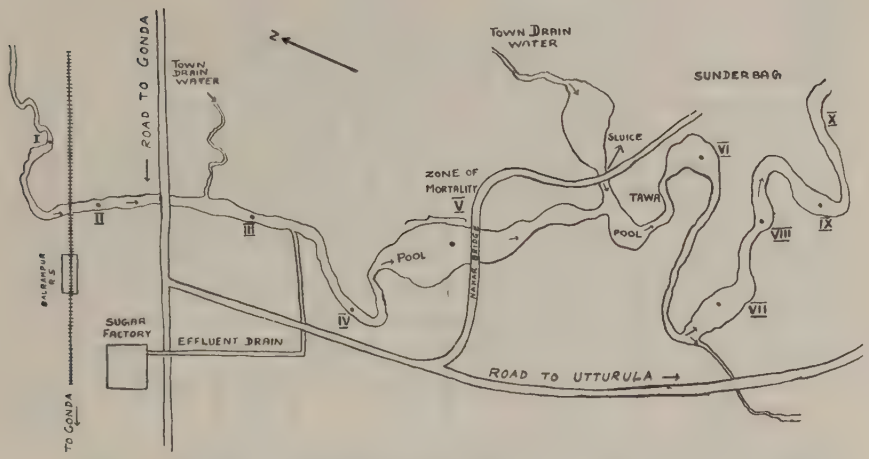


FIG. 1. A diagrammatic sketch map of a section of the Suvaon showing location of the sampling stations above and below the effluent channel.

the sector studied in January to February of 1955. Observations in other years showed generally the same trend of variation. In addition, chemical condition of the deep and extensive pool at station V was studied in greater detail. In this zone dissolved oxygen, carbon dioxide and hydrogen sulphide were determined at various points and at different depths. The oxidation-reduction potential of the bottom mud and at the mud-water interface was also determined at several points to assess the intensity of reducing condition prevailing in the environment.

Temperature, turbidity and colour.—In the Suvaon where the pollution hazard is mainly due to the decomposition products of chemical and biochemical reactions, the significance of thermal condition of the environment cannot be disregarded, although aquatic life can generally tolerate a wide range of temperature fluctuations. The temperature coefficient of most of the chemical and biochemical processes is positive and high so that the rate of immediate oxidation of organic matter and the production of toxic gases like hydrogen sulphide by the bacterial action have a direct bearing on the thermal condition of the environment. During the present observations in November to January months, the temperature values were generally lowest for the year so that the influence of temperature in furthering the pollution hazard may be considered minimum.

TABLE II

Water quality of river Suvaon at different sampling stations

Sampling stations	Distance from station I in miles	Date	Time	Weather	Temp. ° C.	Turbidity p.p.m.	pH	D.O.	CO_2	CO_3	HCO_3	NO_3	P_2O_5	O.C.	B.O.D.	Colour	Odour
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
I	0	2—2—1955	09·00	Bright	19·1	210	7·7	6·0	8	Nil	100	·05	·24	30	2·8	L. muddy	Nil
II	1	27—1—1955	09·00	,,	18·8	200	7·7	6·2	8	,,	104	·05	·24	32	2·6	,,	,,
III	2	27—1—1955	10·00	,,	21·1	220	7·8	5·3	8	,,	110	·05	·26	32	2·6	,,	,,
IV	3	31—1—1955	15·00	,,	22·0	120	7·2	2·2	16	,,	176	·05	1·2	360	740·0	Blackish	Org. (H_2S)
V	4	28—1—1955	12·00	,,	19·3	160	7·0	Nil	22	,,	200	·06	·72	300	500·0	Black	,,
VI	6	28—1—1955	12·00	,,	24·0	30	7·4	0·6	10	,,	210	·08	·70	260	380·0	L. black	Org.
VII	7	2—2—1955	11·00	,,	20·0	25	7·6	4·4	8	,,	200	·05	·68	86	80·0	,,	F. (Org.)
VIII	8	2—2—1955	12·00	,,	20·6	25	7·8	6·0	6	,,	168	·05	·30	56	8·0	Clear	Nil
IX	10	31—1—1955	11·00	,,	20·1	20	7·8	6·0	6	,,	142	·05	·20	40	3·2	,,	,,
X	11	31—1—1955	12·00	,,	20·0	25	7·8	6·3	6	,,	136	·05	·20	36	3·0	,,	,,

Turbidity and colour have a direct bearing on light penetration, bottom condition, bacterial concentration and various other elements in an aquatic environment. It is generally found that with the introduction of a highly turbid and coloured effluent, turbidity of the receiving water is abruptly increased near the outfall but the subsequent process of clarification of stream water is slow. In the Suvaon, however, turbidity shows a marked decrease immediately below the outfall and while the values somewhat increase in the septic zone of "Nahar-bridge" pool, water further downstream becomes almost clear showing a turbidity of 30 p.p.m. and less (*cf.* Table II). Two factors responsible for this phenomenon may be (i) the stagnated condition of the stream in the non-monsoon period with no flow of turbid water from upstream to the point of effluent confluence, and (ii) turbidity of water in the upstream zone of the Suvaon, which is due to peptised clay sol, may become unstable incident to chemical and physical interaction with the effluent.

Dissolved oxygen, *biochemical-oxygen-demand* and *oxygen consumed.*— In a study of this type of heavy organic pollution, determination of oxygen balance in the system is very important. Although major part of the oxidation is of biochemical nature so that determination of dissolved oxygen and biochemical-oxygen-demand gives a more complete picture of the extent and nature of pollution, some constituents of the effluent following precipitation may undergo chemical or biological oxidation at the stream bottom. Oxygen condition and biochemical-oxygen-demand of the stream in the clear water zone is quite satisfactory, but there is a sudden fall in dissolved oxygen with an abrupt rise in biochemical-oxygen-demand below the outfall and further downstream at station V, water is totally depleted of its dissolved oxygen and biochemical-oxygen-demand shows a high value. Recovery zone commences downstream of station V where the oxygen condition registers a slow improvement, complete normal condition being obtained at station VIII at a distance of about 5 miles from the outfall. At this station the water is fairly alkaline with the pH value of 7·6 and dissolved oxygen value of 6·0 p.p.m. The light-black colour of water and the organic smell of hydrogen sulphide are not perceptible as also in the other downstream stations. In the extensive "Nahar-bridge" pool it was observed that though a very low concentration of dissolved oxygen (0·1–0·3) was maintained at the surface layer and along the marginal zones, main bulk of the water was completely devoid of dissolved oxygen. Hydrogen sulphide concentration ranged from 16·4 to 22·6 p.p.m. and carbon dioxide from 24·2 to 28·6 p.p.m. The highly reducing condition in the septic zone was exhibited by extremely low values of red-ox potential. The surface water

TABLE III

Relative abundance of fish species at different sampling stations in the area under investigation in 1954–55

	Species	Sampling stations								
		I	II	III	IV	V	Between V & VI Tawa pool	Between VII & VIII	IX	X
1.	*Gadusia chapra*	X	X	..	..	..	..	..	..	X
2.	*Notopterus chitala*	..	..	..	..	..	..	..	X	X
3.	*Notopterus notopterus*	X	X	X	X	X	..	X	X	X1
4.	*Oxygaster bacaila*	X5	X3	X5	X	..	..	X	X	..
5.	*Oxygaster gora*	X	X	..	..	..	..	X	X	X2
6.	*Chela atpar*	..	X	..	..	..	..	..	X	X1
7.	*Chela laubuca*	..	X	..	..	..	..	..	..	X1
8.	*Esomus danricus*	..	..	X2	X1	..	..	..	..	..
9.	*Rasbora daniconius*	..	..	X	X2	..	X2	..	X	..
10.	*Amblypharyngodon mola*	X6	X4	X4	X3	..	X2	X	..	X3
11.	*Aspidoparia morar*	..	X3	..	..	X	..	X	..	..
12.	*Catla catla*	..	X1	..	..	..	..	..	..	..
13.	*Cirrhina mrigala*	..	X2	X1	..	..	..	..	..	X3
14.	*Cirrhina reba*	..	X2	X1	..	..	X7	X3	X3	X2
15.	*Crossocheilus latius*	..	X	..	...	..	X1	..	..	..
16.	*Labeo bata*	X1	..	X	..	..	X2	..	..	..
17.	*Labeo calbasu*	..	..	X	..	..	..	..	..	..

TABLE III—*Contd.*

	Species	Sampling stations								
		I	II	III	IV	V	Beteewn V & VI Tawa pool	Between VII & VIII	IX	X
18.	*Labeo dero*	..	..	..	..	..	X2	..	..	X1
19.	*Labeo dyocheilus*	X2	..	..	..	..	X4	X	..	X2
20.	*Labeo rohita*	X3	X2	X1	..	..	..	X	..	..
21.	*Puntius conchonius*	X5	X3	..	..	..	..	X2	X3	..
22.	*Puntius phutunio*	..	X1	..	..	..	X4	..	X	..
23.	*Puntius sarana*	X1	X2	X4	..	X2	X1	..	X1	X1
24.	*Puntius sophore*	X4	X7	X4	X2	X1	X8	X2	X3	X2
25.	*Puntius ticto*	X	X2	X3	..	..	X2	X3	..	X2
26.	*Rohtee cotio*	X1	X4	X3	..	..	..	..	X	X2
27.	*Lepidocephalichthys guntea*	X	X	..	..	..	..	X	..	..
28.	*Botia dayi*	X	..	..	..	..	..	..	..	..
29.	*Nemachilus zonatus*	..	X1	X	..	..	..	..	..	..
30.	*Clarias batrachus*	..	..	..	X2	X2	..	..	..	..
31.	*Heteropneustes fossilis*	X1	X	X	X	X1	..	..	X1	X1
32.	*Ompok bimaculatus*	X2	X2	X4	..	X	..	..	X	X2
33.	*Wallago attu* ..	X2	X2	X1	..	X10	..	..	X1	..
34.	*Pseudeutropius atherinoides*	X6	X5	X2	X3	X	..	X	..	X2
35.	*Mystus aor* ..	..	..	..	X	..	..	..	..	..	..

TABLE III (*Contd.*)

Species	Sampling stations								
	I	II	III	IV	V	Between V & VI Tawa pool	Between VII & VIII	IX	X
36. *Mystus bleekeri*	X1	..	..	..	..	..	..	X	X
37. *Mystus cavasius*	X2	X1	X	..	..	..	X	X	.
38. *Mystus menoda*	..	..	..	..	X1	..	.	.	..
39. *Mystus seenghala*	..	..	X1	..	X1	.	..	..	..
40. *Mystus tengara*	..	X	..	..	..	..	..	.	.
41. *Mystus vittatus*	..	X1	X2	..	..	..	X	..	..
42. *Rita rita*	X	..	..	..	X	X	X1	X1	X1
43. *Xenentodon cancila*	..	X1	X1	..	X3	X1	X	.	X2
44. *Ambassis nama*	X7	X3	X5	..	..	X	X2	X	X4
45. *Ambassis ranga*	X10	X5	X7	X	..	X	X3	X	X5
46. *Anabas testudineus*	..	..	..	X	..	..	..	..	..
47. *Nandus nandus*	..	..	..	..	..	..	X	X	X3
48. *Glossogobius giuris*	X1	X	..	..	X	..	.	..	..
49. *Ophicephalus marulius*	X2	..	X	X2	X3	..	..	X	.
50. *Ophicephalus striatus*	..	..	..	..	..	X1	..	..	X	X1
51. *Ophicephalus punctatus*	..	X	..	..	X2	..	..	X	XI
52. *Colisa colisa*	..	X	..	..	..	..	..	..	X	X1
53. *Colisa fasciatus*	X	..	X	..	..	..	..	X	X3
54. *Mastacembelus pancalus*	X	..	..	..	..	..	..	..	X2
55. *Macrognathus aculeata*	X	..	..	..	..	..	..	..	X1
Total number of species	30	33	28	12	17	14	20	26	30

was practically neutral in reaction with pH values from 7·0 to 6·9 but the water column from sub-surface to the bottom with pH ranging from 6·6 to 6·7 showed a slightly acidic reaction.

(*ii*) *Biological Conditions*

Regular collections of fish species, plankton and bottom biota were made generally in deeper portions of the Suvaon and as far as feasible nearest to the respective sampling stations. Fishing was done by local fishermen employing their own gear and large scoop nets were used at all the sampling stations except in the pool at station V where mahajal was operated.

Fish.—Fifty-five species of fish were collected during the study period. Table III lists the fish species collected and their relative abundance at different sampling stations during the 1954–55 field surveys. The clear water zone upstream of the outfall yielded over 45 species in which major carps represented by young (0–year class) of *Cirrhina mrigala*, *Labeo rohita* and *Catla catla* formed the bulk by weight in the order of abundance stated. *Wallago attu* (size-range of 300–600 mm.) was the next most predominant species. The minor carps and weed fish represented by several species and some small-sized cat-fishes like *M. vittatus*, *M. cavasius* and *P. atherinoides* were also very common in the area. Rest of the species were generally available in fairly good numbers. In the stretch below the outfall only 12 species were available of which *A. mola*, *R. daniconius*, *P. sophore*, *C. batrachus*, *P. atherinoides* and *O. marulius* were somewhat common, the other six species occurring stray. Except for *O. marulius* and *C. batrachus* all the others are small-sized and of insignificant importance as commercial fisheries. Major carps and large-sized catfishes were totally absent in this zone. Further downstream in the extensive pool at station V, although 16 species were collected, *Wallago attu* was the most abundant species both as regards to number and weight. Out of 249 individuals collected from this region, 167 specimens (of the size-range 275–500 mm.) were of *W. attu*, with *Ophicephalus* spp., *P. sophore*, *M. mercenaria* and *X. cancila* fairly common and the other species occurring stray or rare. Major carps were totally absent in this section also. It may be pertinent to mention that the fishes taken in this section were mostly emaciated and anæmic with stunted growth. Downstream in the shallow pool near Tawa, the species composition of fish was observed to be of specialised type with *P. sophore*, *C. reba*, *L. dyocheilus*, *P. phutunio* and *P. ticto* constituting the bulk. Further downstream the number of species available generally increased till at station X, 8 miles below the outfall, 30 species were taken majority of which were in fairly good numbers. The section of the river from below the Tawa pool to Sunderbag

is generally shallow so that velocity of flow was fairly high as compared to the upstream sections of the Suvaon. Consequently most of the fish species encountered at stations IX and X were weed fish, minor carps and catfishes which do not attain a large size. It is interesting to note that the major carps which formed the dominant group in the upstream stations were totally absent in all the downstream stations below the outfall. The species composition of fish taken in different sectors of the Suvaon showed that only *Wallago attu* and two species of *Ophicephalus* were available in good numbers in the 2-mile stretch below the outfall as against the large variety of species in good numbers taken in the stretch upstream of the outfall and at stations IX and X. *Wallago attu* and *Ophicephalus* spp. are known to occur and thrive under conditions of gross pollution and low dissolved oxygen concentration, but the condition of these fish in the septic zone of station V appeared to be unhealthy suggesting that conditions of existence obtaining in this zone were not conducive for normal growth.

Plankton.—The densities of plankton organisms at various sampling stations are listed in Table IV. A few free-living nematodes were available in the samples taken from the stretch upstream of the outfall but these forms were not encountered at any of the downstream stations. The zooplankton concentration in the clear water zone was quite rich both as regards to number and species. Crustaceans with Nauplius stage of Copepoda formed the dominant group and Rotifera were represented by a large variety of species. Immediately below the outfall, zooplankton counts showed very appreciable fall and further reduction in number was observed at station V in the septic zone. Protozoa, however, showed comparatively higher counts with *Paramœcium* sp. and amœboid forms, *Arcella* spp., and *Centrophyxis* spp., appearing as dominant species. Rotifera, represented by a single member of *Monostyla*, were present only in very small numbers and Crustaceans were totally absent. It may be relevant to mention that the Ciliate form, *Vorticella* sp., appeared for the first time in the septic zone and while its number increased considerably at station VI, it was not encountered at any of the downstream stations. Zooplankton, represented only by Protozoans, registered a further fall at station VI but conditions thereafter had obviously improved as reflected by an abrupt increase in plankton counts at station VIII and further downstream with Crustaceans and Rotifera reappearing in good numbers. Protozoa count, however, showed a progressive decrease and was mostly represented by amœboid forms, *Arcella* and *Centrophyxis*.

The trends in phytoplankton appear to follow the same general pattern as observed in zooplankton with rich concentrations in the clear water zone,

TABLE IV

Densities of plankton per 100 litres of water at different sampling stations in the Suvaon stream during 1954–55 field survey

	Sampling stations									
	II	III	IV	V	Between V & VI (Tawa pool)	VI	VII	VIII	IX	X
ZOOPLANKTON—										
Protozoa ..	612	576	1,517	1,102	1,050	836	..	648	384	378
Rotifera ..	3,706	1,584	111	58	..	105	..	2,304	2,176	184
Crustacea:										
(i) Nauplius stage	5,270	4,032	296	..	..	350	..	2,592	5,760	2,944
(ii) Copepoda	374	288	..	..	..	..	..	360	128	92
(iii) Cladocera ..	136	..	..	..	..	..	..	..	64	46
(iv) Ostracoda	34	..	..	..	..	..	..	..	8	23
Total organisms ..	10,132	6,480	1,924	1,160	1,050	1,291	..	5,904	8,520	3,667
PHYTOPLANKTON—										
Myxophyceæ ..	1,800	9,200	48,200	3,800	..	3,200	5,400	2,400	..	200
Bacillariaceæ ..	2,800	2,000	5,616	400	..	1,000	1,600	1,200	800	200
Chlorophyceæ ..	20,100	1,800	5,200	800	..	1,600	3,400	4,800	600	200
Charophyceæ ..	..	..	..	200	..	..	..	..	..	..
Euglenaneæ ..	..	..	200	..	..	1,800	8,600	7,200	..	..
Total organisms ..	24,700	13,000	59,216	5,200	..	7,600	19,000	15,600	1,400	600

specialised types of algæ in considerably reduced numbers in the septic zone and their reappearance in fair concentration in most of the downstream stations. Chlorophyceæ with *Zygnema* and *Spirogyra*, as dominant forms, was the most important group at station II, whereas Myxophyceæ with *Oscillatoria* sp. was conspicuous at station III. It may be stated that the algæ count was considerably low at this station which might be due to detrimental effect of the effluent reaching up to this sector as a result of the reverse currents produced by discharge of the wastes under static condition of the stream. The algæ count registered a maximum at station IV below the outfall, with Myxophyceæ mainly represented by *Oscillatoria* sp., forming the most dominant group. *Synedra* sp., *Gyrosigma* sp., *Navicula* sp., and *Coscinodiscus* sp. among Diatoms and *Phyllosiphon* sp. among Chlorophyceæ were the other forms conspicuous in this sector. The maximum concentration of algæ in this section is probably due to fertilising effect of the effluent and the clarity of stream water incident to abrupt reduction in turbidity ensuring from the physical and chemical interaction of the constituents in the effluent and the clay sol in the stream water. In the deep and extensive pool at station VI the algæ concentration showed considerable reduction both as regards to species and number but it is interesting to note that *Chara* sp., generally associated with swamp-like odour, appeared in this sector for the first time and was not encountered in any of the downstream stations. The steep fall of Myxophyceæ concentration in the septic zone is probably due to decay of these forms which sets in generally, due to decay of highly nitrogenous organic matter in which partially decomposed sulphur and phosphorus compounds play a large part.

Conditions downstream had obviously improved and there was a progressive increase in the algæ concentration both as regards to number and species in the stretch between stations VI and VIII. However, subsequent low concentration of the algæ at the last two stations is difficult to explain unless it be that the low counts might have some bearing on the generally shallow condition of the stream-bed in this sector and as has been observed the velocity of flow was found to be fairly high at these stations.

Bottom biota.—Collection of bottom organisms was possible at most of the sampling stations and total animals collected in the nine samples, with Surber's Stream-bottom Sampler, are listed in Table V. Molluscs, aquatic insects and other forms were well represented in the section upstream of the outfall. *Chironomus* larvæ and Rat-tailed maggots, both known to thrive under anaerobic conditions, occurred in greater numbers in the stretch below the outfall as against the total absence therefrom of all molluscan

forms, some of the aquatic insects like Odonata and Ephemeroptera nymphs, aquatic oligochaete (*Naidium* sp.) and other miscellaneous forms. Further downstream in the septic zone there was a sudden increase in number of Coleoptera larva, *Chironomus* larvæ and Rat-tailed maggots and some of

TABLE V

Densities of bottom animals per square yard at different sampling stations in the Suvaon stream during 1954–55 *field survey*

	Sampling stations						
	II	III	IV	V	VI	VIII	X
MOLLUSCA—							
Viviparus sp.	1	4*	1*	..	11	8	2
Gyraulus convexiusculus	1	..	..	1	2	2	4
Lymnea (*Pseudosucinea*) *luteola*	2	..	..	..	1*	2	1
Indonaia sp.	..	1	..	..	..	..	1
Parreysia sp.	3	..	..	..	2	4	1
Pisidium sp.	1	1*	..	..	1*	1	..
AQUATIC INSECTS—							
Coleoptera larvæ	3	3	5	59	7	15	5
Odonata nymphs	1	..	..	..	1	2	2
Ephemeroptera nymphs	2	..	..	..	3	5	..
Hemiptera—*Nepa* sp.	..	1	..	4	..	..	2
Diptera (*a*) *Chironomus* larvæ	6	2	9	37	10	16	11
(*b*) Rat-tailed maggots		1	6	12	..	.	..
OTHER FORMS—							
Aquatic oligochaetes (*Naidium* sp.)	11	3	..	3	4	7	19
Hydracrina (water-mites)	5	..	..	..	2	1	2
Tubifex worms	1	..	..	2	1	..	..
Total number of animals	38	16	21	118	45	63	50

* Dead shells only.

the forms encountered in the clear water zone reappeared in smaller numbers. It is interesting to note that Coleoptera larvæ and *Chironomus* larvæ which occurred at all the sampling stations formed the most dominant forms only in the septic zone. Further downstream most of the forms observed in the clear water zone reappeared generally in far greater numbers in the stretch between stations VI and X.

IV. Discussion and Recommendations

It has been reported by the local fishermen that wastes from the Balrampur Sugar Factory cause mortality of fish in the 2-mile stretch of the Suvaon below the outfall. According to them fish mortality, which is an annual feature, generally occurs 10 to 15 days after commencement of the crushing season and once the mortality begins almost all the fish in the affected stretch succumb within 48 hours. The State Department of Fisheries estimate the annual mortality of over 100 maunds (3,700 kilograms) of fish. It may be relevant to mention here that the fishery rights of the Suvaon are leased out every year towards the end of the monsoon season when the lessees erect barriers across the Suvaon near Sunderbag against downward migration of fishes into Chandatal. The Suvaon and specially the extensive "Nahar-bridge" pool are then systematically and vigorously fished.

The pollution of the stream has been shown to be purely of organic nature (*cf.* Tables II to V) and results of bio-assay experiments conducted in the field laboratory together with analysis of the effluent have not revealed the presence of any toxic substance which might constitute a direct hazard to fish life. The pollution is mainly due to decomposition of organic matter by the action of certain types of bacteria and other micro-organisms which consume the organic matter and combine them with oxygen available in the environment (biological oxidation) and associated with this process, there may be chemical and biochemical oxidation also. The first and primary impact of wastes, therefore, is on the oxygen budget of the stream. The capacity of a stream to counteract this hazard is dependent on processes of self-purification available therein. The Suvaon, as has been described, is a monsoon-fed stream which assumes characteristics of a water-logged channel by the month of December when the sugar factory commences operations. Thus there is no constant and regular supply of oxygenated freshwater from upstream to the point of influence and under the static condition of the stream, restoration of the oxygen level, in main, is by natural diffusion from atmosphere which is an extremely slow and inadequate process. Consequently there is a rapid depletion in dissolved oxygen of

the Suvaon and in the "Nahar-bridge" pool the anaerobic conditions become apparent not only at the zone of mud-water interface but even in the water column a few inches below the surface. The southern boundary of the pool is a raised masonry structure supporting the road bridge, and this elevation obstructs the free flow downstream so that the effluent after depositing most of its suspended matter and undergoing chemical interactions with environmental water flows past as a supernatant liquid. The anaerobic condition developed in the pool with other associated favourable condition like low oxidation-reduction potential obtaining therein and the presence of sufficient organic matter together stimulate activation of sulphur-reducing bacteria producing hydrogen sulphide, a gas highly toxic to fish life. Klein (1957) has shown that conditions essential for the bacterial production are (i) absence of free oxygen and nitrates, (ii) presence of organic matter and (iii) fairly high temperature. The sulphur-reducing bacteria are therefore likely to be specially active in polluted rivers devoid of dissolved oxygen particularly in the mud column of the stream-bed. Putrescent river mud harbouring sulphur-reducing micro-organisms generally contains black ferrous sulphide (FeS) formed by the interaction of hydrogen sulphide and ferrous compounds. Heukelekian (1948) found that sewage contains only a few sulphur-reducing bacteria but much larger numbers occur in sewer growths and in sewage sludge. Apparently active growth of these micro-organisms takes place only when the oxidation-reduction potential of the sewage falls to a certain level. According to Mortimer (1941, 1942) the approximate potential ranges at which the following reductions occurred were (i) nitrate to nitrite: 0·45 to 0·40, (ii) nitrite to ammonia: 0·40 to 0·35, (iii) ferric to ferrous: 0·30 to 0·20, and (iv) sulphate to sulphide: 0·10 to 0·06; the approximate oxygen concentration for these reactions were respectively 4·0, 0·4, 0·1, and 'zero' mg./litre. In addition to the very low red-ox potential and the conditions favouring activity of the sulphur-reducing bacteria, there is a constant supply of sulphate from the effluent to the field of biological and chemical reactions and according to the fundamental law of chemical dynamics, these conditions will further enhance activity of the micro-organisms resulting in increased production of hydrogen sulphide. Doudoroff and Katz (1950) have shown that concentration of the gas below 10 p.p.m. is lethal to sunfish, trout, suckers, minnows, goldfish and carps. In the bio-assay experiments with *Puntius tieto* and *Oxygaster bacaila* from the clear water zone, it was observed that at low oxygen level (1·0 to 2·0 p.p.m.) the lethal range for hydrogen sulphide was 5·0 to 9·0 p.p.m. When this lethal concentration is exceeded in the "Nahar-bridge" pool, the fish succumb under the synergetic action of low

oxygen and lethal concentration of hydrogen sulphide and a large-scale mortality of fish occurs in the 2-mile stretch below the outfall killing practically all the species in the region.

It is likely that due to cumulative effect of untreated sugar wastes discharged into the Suvaon, the ecological conditions created therein are so unfavourable that fish from the Rapti avoid large-scale migrations into the Suvaon. Further the State Department of Fisheries collect fry and fingerlings of major carps for stocking departmental and private tanks located in the vicinity and the Suvaon is the main source of their supply. In view of the annual recurring loss to the existing fishery of the Suvaon and a distinct possibility of enhanced natural stocking thereof, once the favourable ecological conditions are created, it is essential that corrective measures be adopted to render the effluents innocuous to aquatic life.

In view of the fact that the factory operates only on a seasonal basis and that there is no scarcity of land in the vicinity, cheap and effective measures for treatment of the wastes are recommended. The remedial measures, based on the detailed stream survey data, if strictly implemented, are expected to improve ecological conditions in the Suvaon to a stage where no adverse effect on its fisheries is likely to be apparent.

The effluent contains quantities of sugarcane pulp fibres, soil, lime, etc., and may therefore be subjected to screening or allowed to pass through a settling tank so that the suspended matter is separated from the liquid phase. If necessary, rapid coagulation of the latter may then be obtained by treatment with coagulants. To reduce the load of dissolved organic matter, the clarified liquid may then be oxidised by splash system. This can easily be accomplished by controlling its flow so that a thin layer of the effluent is diverted into a very wide channel and allowed to fall on cross-baffles from a height of 2 to 3 feet. The clarified and aerated effluent may then be lagooned in a suitable pond. As the main cause of mortality of fish has been traced to the production of hydrogen sulphide by the activity of sulphur-reducing bacteria, a bacterial treatment of the effluent is considered essential in the last phase before discharging the effluent at controlled velocity into the Suvaon. This may be effected by injecting the effluent with bleaching-powder solution or chlorine water from a small chlorination plant.

V. Summary

The pollutional effects of the wastes from a sugar factory at Balrampur (U.P.) on the fish and fishery of the river Suvaon, a small tributory of the

Rapti, has been studied in detail. Chemical and physical analysis of the effluent and the bio-assay experiments, conducted with fish from the fresh-water zone, show that the wastes do not contain any substances directly toxic to fish life, the pollution being purely of organic nature. The primary effect of the wastes is to deplete environment of its dissolved oxygen and following the process of decomposition of organic matter, anaerobic condition in the environment is developed which in association with other favourable elements like low red-ox potential, presence of sufficient organic matter and constant supply of sulphate from the wastes, stimulate activation of sulphur-reducing bacteria producing hydrogen sulphide, a gas highly toxic to fish. At the very low dissolved oxygen level, hydrogen sulphide becomes lethal at a sub-lethal concentration and a large-scale fish mortality results in the 2-mile stretch of the river below the outfall. The fish mortality being of annual occurrence the assessed loss to the fishery of the Suvaon is quite considerable. Study of chemical quality of the water and distribution of fish, plankton and bottom animals in the 11-mile stretch of the Suvaon show that very unfavourable ecological conditions exist for about two miles below the outfall. As the factory operates on a seasonal basis only and that there is no scarcity of land in the locality, cheap and effective remedial measures for improvement of the environment have been suggested.

VI. Acknowledgements

We are indebted to Dr. V. G. Jhingran for his constant encouragement during the progress of work and to Messrs. S. J. Karamchandani and S. B. Singh for their assistance in analysis of samples on bottom biota and phyto-plankton. Our sincere thanks are due to the Manager, Balrampur Sugar Factory and to the State Department of Fisheries for their help and co-operation in the field-work.

VII. References

American Public Health Association. 1946 — *Standard Methods for the Examination of Water and Sewage*, 9th Edition, New York.

Doudoroff, P. and Katz, M. 1950 — Critical review of literature on the toxicity of industrial wastes and their components to fish. I. Alkalies, Acids and Inorganic Gases. *J. Sewage and Industrial Wastes*, **22** (11), 1432–58.

Heukelekian, H. 1948 .. Bacteriological aspects of hydrogen sulphide production from sewage. *Sewage Wks J.*, **20**, 490–98.

Klein, Louis. 1957 .. *Aspects of River Pollution*, Butterworths Scientific Publications, London.

Mortimer, C. H. 1941 .. The exchange of dissolved substances between mud and water in lakes. Part I. *J. Ecol.*, **29**, 280–329.

————. 1942 .. The exchange of dissolved substances between mud and water in lakes. Part II. *Ibid.*, **30**, 147–201.

Motwani, M. P., Banerjea, Santimoy and Karamchandani, S. J. 1956 Some observations on the pollution of the River Sone by the factory effluents of the Rohtas Industries at Dalmianagar (Bihar). *Indian J. Fish.*, **3** (2), 334–67.

APPENDIX A

1. Name of the factory: Balrampur Sugar Factory

2. Locality and address: P.O. Balrampur, District: Gondat (U.P.), Railway Station: Balrampur N.E. Railway.

3. Plant operation:

	Hours per week	Days in year
(i) Average ..	150	100
(ii) Maximum ..	168	142

4. Water-supply:

Source	Average gallons per day	Maximum gallons per day	Treatment of water, if any
Tube-wells	7,80,000	7,80,000	None

(i) For drinking: .. 10,000 gallons

(ii) For industrial use: .. 6,50,000 gallons

(iii) For cooling of factory machinery .. 1,20,000 gallons

5. Raw material/materials used in the process:

(i) Average quantity per day .. 22,500 maunds sugarcane

(ii) Maximum quantity per day .. 24,000 maunds sugarcane

6. Chemical used, if any:

	Sulphur used as SO_2	Lime
(i) Average quantity ..	5 maunds per day	35 maunds per day
(ii) Maximum quantity ..	8 maunds per day	45 maunds per day

7. Wastes:

	Cane washings	Press washings	Lime cake	Condenser washings
(i) Quantity ..	Nil	Nil	500 mds. per day	3,00,000 gallons per day
(ii) Chemical character of the wastes ..	..	..	Presence of Ca, S, P, N, compounds and sugar	Trace of sugar SO_2
(iii) How estimated ..	..	..	Weighed	By calculation

8.	By-products:	Mollasses
	(i) Quantity ..	800–900 maunds produced per day
	(ii) Their disposal ..	Stored in steel tanks and sold to buyers
9.	Residential colony:	
	(i) Number of persons provided within the factory	400 persons
	(ii) Mode of disposal of—	
	(*a*) Night soil ..	Incinerator
	(*b*) Kitchen washings	Through drains to main factory drain
10.	Outlet(s) for factory and residential colony wastes and where to:	Through factory main drain to Suvaon Nala
11.	Description of outlet(s):	Two drains—24 × 12″, rectangular
	(*a*) Length, size and shape ..	Length: 11,000′ and 400′
	(*b*) Location ..	Drain taken from north side of factory through colony
	(*c*) Elevation ..	1′ to 6″
12.	Any further information:	

GROWTH AND CALORIFIC APPROXIMATION IN THE SPECKLED TROUT

(*Salvelinus fontinalis*)

By S. V. Job*

(*Central Marine Fisheries Research Station*)

Introduction

From the point of view of energy metabolism, appropriate measures of the rate of oxygen uptake would indicate the energy turnover or the capacity of the organism to perform external work in relation to its size and under the prevalent environmental conditions. Estimates of oxygen uptake when considered in conjunction with growth rate and calorific equivalent of the metabolic rate, would permit estimates of the total energy requirements of the individual. It has long been established, that the calorific equivalent of food consumed corresponds to the heat output *plus* the heat equivalent of excreta, and that such a measurement of metabolism can be verified also by indirect calorimetric methods based on the gas exchange of the animal.

A number of early workers: Rubner (1902), Lindstedt (1914), Zuntz (1914) and Wundsch (1934) have established the essential validity of indirect calorimetric methods and the present work based on some preliminary experiments carried out on the speckled trout adds further evidence. Especially in the light of current trends where culture fisheries as a branch of science is given as much importance as capture fisheries, economy in food supply with the maximum of production can be accurately assessed with some knowledge of the energy turnover of the population in question. It is more to stimulate further interest in this field of study rather than to display any completeness of the enquiry that the following are presented.

Material and Methods

The data of oxygen uptake for this study were actually extracted from Job (1955). The apparatus used is shown in Fig. 1. Briefly the device is a double-walled drum—the outer being glass and the inner, metal. The base of the drum also of metal, rests on a turntable. A metal rim is mounted on the free end of the glass wall and is firmly clamped to the base by means

* Present Address: University Zoology Research Laboratory, University of Madras.

of lucite brackets. There are two openings on this rim. Through one a measured quantity of water can be introduced from a graduated cylinder mounted on the rim itself, by opening a long handled screw valve. The other opening is for the thermometer. After filling the chamber with water it is sealed from the atmosphere by a rubber gasket (the inner tube of a small aeroplane wheel) which when inflated bound against the metal rim and the

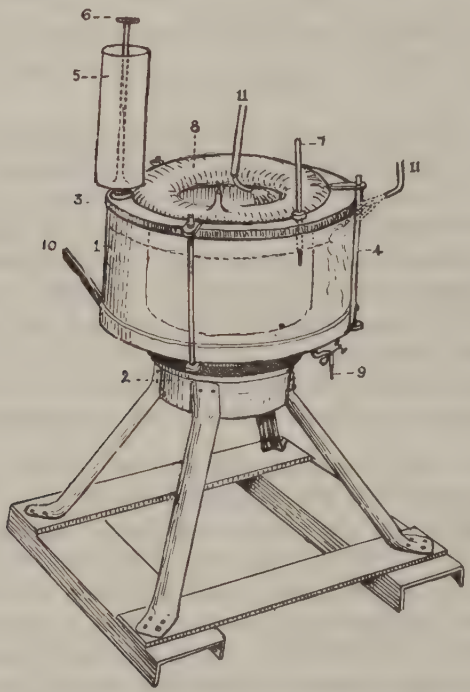


FIG. 1. Apparatus for measuring the active metabolism of fish. (1) Drum, (2) Turntable, (3) Metal rim, (4) Lucite bracket, (5) Graduated cylinder, (6) Screw valve, (7) Thermometer, (8) Rubber gasket, (9) Outlet, (10) V-belt connecting turntable to reduction speed gear, (11) Water jets. [(For an improved and more efficient version of the same apparatus, *see* Fry in Brown (1957)].

inner wall of the drum. Water could be drawn for analysis through the other opening located on the inner wall close to the base of the drum. Since the system is a closed one water could be drawn out only by a simultaneous introduction of water into it. At each sampling therefore 100 ml. of water was introduced from the graduated cylinder and the same amount drawn out. This procedure ensured the constancy of the volume of water in the

chamber. During the experiment the entire chamber could be rotated at any constant speed ranging from 1 to 200 r.p.m. and its direction changed at will with the help of a variable speed reduction gear powered by a ·25 HP motor. The size of the chamber used was such as to allow enough room for the fish to swim actively. With the help of water jets playing both on the inside and outside of the chamber the temperature could be maintained at any level to within $\pm$ 0·2° C.

The chamber was filled with water at the desired temperature and the fish introduced into it. The partly inflated rubber gasket was pushed down into position and rapidly inflated with both the inlet and the outlet open, so as to equalize the pressure inside the chamber to that of the atmosphere, as otherwise the fish released air into the chamber creating air pockets. The gasket was now squeezed all round in order to release any air lock that might have been formed. The chamber was now rotated rapidly for 30 secs., before the initial sample of the experiment was drawn and from then on at intervals of half to one hour as the case may be, samples were drawn for analyses. The speed and direction of the chamber were such as to make the fish swim actively against the current and maintain a steady position in the chamber—the fish not being allowed to move forward or slip back.

In spite of the seal, some contamination of the water in the chamber especially when the partial pressure of oxygen was low took place through diffusion from the gasket as well as from the atmosphere itself. Suitable corrections were made for this error. The rate of oxygen consumption was calculated from the mean rate of fall in the dissolved oxygen against the total volume of the water in the chamber and expressed in ml./hr. For an improved model of the apparatus please see Fry, 1957.

The feeding experiments were performed on two fish of nearly the same size and average weight of 89 gm. at 17° C. In order to obtain the calorific approximations the fish were held in well-aerated water in a trough of about 10 L. capacity. The fish were fed with fresh minnows *ad libitum* over a period of two weeks. After some training the fish learnt to take the food almost as it was being offered. The unconsumed remnants of the minnows were removed one hour after feeding. The insoluble fæcal matter was collected every 12 hrs. and dried to a constant weight. The heat of combustion of the dried matter was measured according to the procedure described in *Parr Manual No.* 120 (1948)* using a single valved oxygen bomb

* Oxygen Bomb Calorimetry and Oxygen Bomb Combustion Methods. *Parr Manual* 120, 1948, pp. 79. Parr Instrument Co., Moline, Ill., U.S.A.

and a plain calorimeter. Briefly the apparatus consists of three parts: (1) The oxygen bomb in which the material whose heat of combustion is to be determined is ignited electrically in an atmosphere of pure oxygen; (2) The calorimeter bucket holding a measured quantity of water and a Beckman's thermometer and stirrer; and (3) an insulated jacket to prevent changes in the ambient temperature from affecting the temperature in the bucket.

Results and Calculation of Data

As was stated earlier the value obtained from Job (1955) was that an 89 gm. fish consumed 8 lit. of oxygen in two weeks. As there is evidence in the literature to show that fish normally maintains its metabolic rate at or near its maximum this value was taken as such for estimating the calorific output.

During the same period the mean weight of minnows consumed per fish was 91 gm. and the gain in weight, in other words the average growth, was 11 gm. The insoluble fæcal matter collected amounted to 3·3 gm./fish, (dry weight). The calorific value of the minnows was found to be 86·3 cal./100 gm. (wet weight) and for the fæces 2·3 cal./gm. (dry weight). With these basic data the following calculations and approximations were made:

The net food consumed per fish	= (91 — 11)
(*i.e.*), food eaten — weight gained	= 80 gm. wet weight
Calorific value of net consumption	= [80×(86·3/100)]
	= **68·9** cal.
Calories excreted as fæces	= (3·3×2·3)
	= **7·6** cal.

From the analysis provided by Schmidt (1950) and on the basis of the calorific content measured, it was assumed that the food ingested contained 16% of protein (and negligible quantities of fat and carbohydrate) on wet weight basis. Then the weight of protein consumed was [80×(16/100)] = 12·8 gm. It was further assumed that the nitrogen from the metabolism of this protein was excreted in the nitrogenous fractions found by Smith (1929) for the excretion of nitrogen by the carp. From his table for branchial and urinary nitrogen excretion in the carp and from the table of heats of combustion of organic compounds given in Hodgman (1945) it was estimated that the calorific value of such nitrogenous products was 6·49 cal./gm. For details see Table I.

TABLE I

Consolidated table of branchial and urinary nitrogen excretion in the freshwater carp, Cyprinus carpio *(Smith,* 1929*) and heats of combustion of the various compounds (Hodgman,* 1945)

Constituents of excretion	% excreted	Heat of combustion calories	Heat of combustion/gm. calories	Total calories per gm. of excreta
Ammonia ..	60·0	..	..	..
Urea ..	5·3	151·6	28·7	..
Uric acid ..	0·2	460·2	1·6	..
Amine ..	6·6	500·0 (mean)	50·0	..
Creatine ..	5·4	559·8	72·0	..
*Undetermined (Trimethylamine ?) ..	20·5	578·6	84·7	..

* The undetermined part is probably Trimethylamine (Smith, 1929). Prosser *et al.* (1950) however maintain that it is absent from the muscle of eel and carp and hence not likely to be that compound. However for the purpose of calculation it has been taken as such, tentatively.

The metabolism of 12·8 gm. of protein would (on the basis that the ratio of nitrogen in it is $\frac{1}{6}$) result in $(12{\cdot}8/6) = 2{\cdot}13$ of excretory N and the calorific value of this amount would be on the basis of the estimates indicated above $(2{\cdot}3 \times 6{\cdot}49) = 13{\cdot}8$ cal.

Since the calorific value of minnows and salmonoids is not the same conversion of minnows into trout flesh would have probably involved greater retention of the calories consumed. The salmonoids typically have a calorific value of 600–1000 cal./lb., Schmidt (1950). The minnows consumed had on the other hand a much lower value, *i.e.*, 390 cal. lb. (86·3 cal./100 gm.). If a calorific value of 600 cal./lb. (mean) is taken for 11 gm. of trout flesh gained it will reduce the heat output further by $[(600-390)/452] \times 11 = 5{\cdot}1$ cal. Thus the calories dissipated would be $(7{\cdot}6 + 13{\cdot}8 + 5{\cdot}1) = 26{\cdot}5$ cal. On this basis then, the net calorific output would become $(68{\cdot}9 - 26{\cdot}5) = 42{\cdot}4$ cal.

As already stated the calorific value of minnows being low and since they were starved at the time of the experiment, it was assumed that the calorific value obtained with the calorimeter for the minnows represented the heat of combustion of protein and negligible quantities of fat and carbohydrate. From the table given by Kleiner (1948) the oxygen equivalents of combustion of protein was taken to be 4·3 calories per litre. Since the calorific equivalent for fat is also of the same order (4·4 cal. = 1 lit. O_2) and since it has been shown by Schmidt (1950) and Geng (1925) that fish have very little carbohydrate, this factor 4·3 used in the present calculation would be justified.

It works out then, that 42·4 calories of minnows consumed would correspond to 9·8 lit. of oxygen in two weeks. From Job (1955) it was estimated that the net steady consumption of oxygen would be 8 lit. over the same period. Taking into account the wide range of assumptions this figure would seem a remarkably close estimate and establish the essential validity of indirect calorimetry as deduced from oxygen consumption measurements of the fish.

For the convenience of the reader the entire set of calculations is summed up in Table II below.

TABLE II

Data of the entire experiment have been summed up in order to obtain the calorific balance and the main features of the calculations indicated. The experiments were based on two fish of nearly the same size and of mean weight of 89 gm.

Total calories ingested (91 —11) gm. at 0·863 cal./gm.		= **68·9** cal.
Less—		
Calories in fæces 3·3 gm. at 2·3 cal./gm.	= 7·6 cal.	
Calories in other excretions 3·13 gm. at 6·49 cal./gm.	= 13·8 cal.	
Gain in calorific values of trout flesh 11 gm. at 0·68 cal./gm.	= 5·1 cal.	
(Total)		= **26·5** cal.
Net calories expended		= **42·4** cal.
Oxygen equivalent of 42·4 cal. at 4·3 cal./lit. O_2 (42·4 ÷ 4·3)		= **9·8** lit. O_2
Mean value of active metabolism for fish of this size		= **8·0** lit. O_2

SUMMARY

The results obtained from a simple feeding experiment and the active oxygen consumption experiment showed that the metabolic rate can be

equated with the calorific output in the speckled trout with reasonable agreement.

The oxygen consumption of a fish of 89 gm. over a period of two weeks at 17° C. was 8·0 litres. During the same period the metabolic equivalent of the net calories amounted to 9·8 litres (approximate).

Acknowledgement

The matter presented in the foregoing pages formed part of a thesis submitted to the University of Toronto in partial fulfilment of the requirements for the Ph.D. Degree and is released for publication with the courtesy of the School of Graduate Studies of that University. The experimental work was performed in the Ontario Fisheries Research Laboratory at the Zoology Department of the University.

The author records his sincere gratitude to Prof. F. E. J. Fry, Director of the Laboratory, for his guidance and for critical reading of the manuscript. The generous assistance of Mr. Michael Kerr, in part of the experimental work, is gratefully acknowledged.

References

Fry, F. E. J. (in). 1957 .. *The Physiology of Fishes*, vol. 1. Edited by Brown, M.E., Academic Press, New York.

Geng, H. 1925 .. Der Futterwert der Naturlichen Fischnahrung. *Zeits. f. Fischerei und deren Hilfwissenschaften*, **23**, 137–65.

Hodgman, C. D. 1945 .. *Handbook of Chemistry and Physics*. Chemical Rubber Publishing Co., Ohio, U.S.A., 29th Ed.

Job, S. V. 1955 .. The oxygen consumption of *Salvelinus fontinalis*. *Univ. Toronto, Biol. Ser.* 61., *Pub. Ontario Fish. Res. Lab.*, **73**, 39 pp.

Kleiner, I. S. 1948 .. *Human Biochemistry*. C. V. Mosby Co., New York, 2nd Ed.

Lindstedt, Ph. 1914 .. Untersuchungen über Respiration und Stoffwechsel Von Kaltblutern. *Zeit. f. Fischerei*, Bd. **14**.

Prosser, C. L. *et al.* 1950 .. *Comparative Animal Physiology*. W. B. Saunders Co., Philadelphia.

Rubner, M. 1902 .. *Gesetze des Energieverbrauches bei der Ernährung*. Berlin, Wien.

Schmidt, P. J. 1950 .. Analyses of freshwater fishes from Canadian interior provinces. *J. Fish. Res. Bod., Can. Pac. Fish. Expl. Sta., Industrial Memo* **13**, 1–8.

Smith, H. W. 1929 .. The excretion of ammonia and urea by the gills of fish. *J. Biol. Chem.*, **81**, 727–42.

Wundsch, H. H. 1934 .. Nahrung, Verdauung und Stoffwechsel der Firche; in Mongole E., *Handbuch der Ernahrung und des Stoffwechsels der landwirtsch. Nutziere.* (Dorstelbst ansführl. literatur) III Bd. Berlin.

Zuntz, N. 1914 .. *Respiration und Stoffwechsel der Fische.* Deutsch. Med. Wochensehr. Jahrg. **40**.

UTILIZATION OF SALINE MUD FLATS FOR FISH CULTURE—AN EXPERIMENT IN MARINE FISH FARMING

By P. R. S. Tampi

(Central Marine Fisheries Research Station, Mandapam Camp)

Introduction

The scope for economically feasible fish farms in brackish water areas in India has long been realised and practically demonstrated by the numerous fish and prawn farms adjoining the backwaters of Cochin along the west coast. Apart from these even some of the other low-lying saline coastal mud flats of the south-east coast of the Indian Peninsula, which periodically get flooded with sea water but usually with a relatively low biological productivity owing to certain inherent ecological drawbacks, also show potentialities for development. Attempts at fish culture in similar marine environments have not been many in this country except for the earlier enterprises by the Madras Fisheries Department as reviewed by Chacko and Mahadevan (1956). A project was recently undertaken at the Central Marine Fisheries Research Station in order to determine to what extent these apparently low productive areas can be brought under more effective utilization for fish culture purposes and the preliminary results are given in this account.

The scheme was initiated by Dr. N. K. Panikkar while he was the Chief Research Officer of this research station. To him and to Dr. S. Jones, the present Chief Research Officer, the author is grateful for their interest in the work. Dr. V. K. Pillay has been helpful in the analysis of a few mud samples while Sarvashri P. A. Abraham and K. Ramachandran Nair have helped in the routine analyses of plankton and water samples. The construction of the ponds was carried out through the Central Public Works Department.

The Experimental Ponds

The site chosen for the experiment forms part of the saline lagoon on the Palk Bay coast near Mandapam and is more or less typical of the coastal lagoons in this region. Figure 1 shows the general outlay of the experimental pond system. The series of seven ponds are fed by sea water by means of a common supply channel leading directly from the Palk Bay. The in and

out flow is controlled by a main sluice near the seaward end of the supply channel while a similar sluice at the farthest point helps to regulate the supply of water during the monsoon season when the surrounding areas get inundated. The shutters of these two principal sluices slide within grooves built in the masonry work on either side and are operated on the screw system on a central shaft. Besides the main sluices there are smaller subsidiary sluices connecting the ponds independently with the feeder canal, each of which is guarded by a pair of shutters, one with a velon screen and the other of wood for completely closing the gates. The ponds are formed by the excavation of the earth and the clay thus obtained is stabilised into bunds. The inset in Fig. 1 shows a cross section of the bund which is provided with nearly 3 feet of coral stone pitching at the base of the slope resting on a

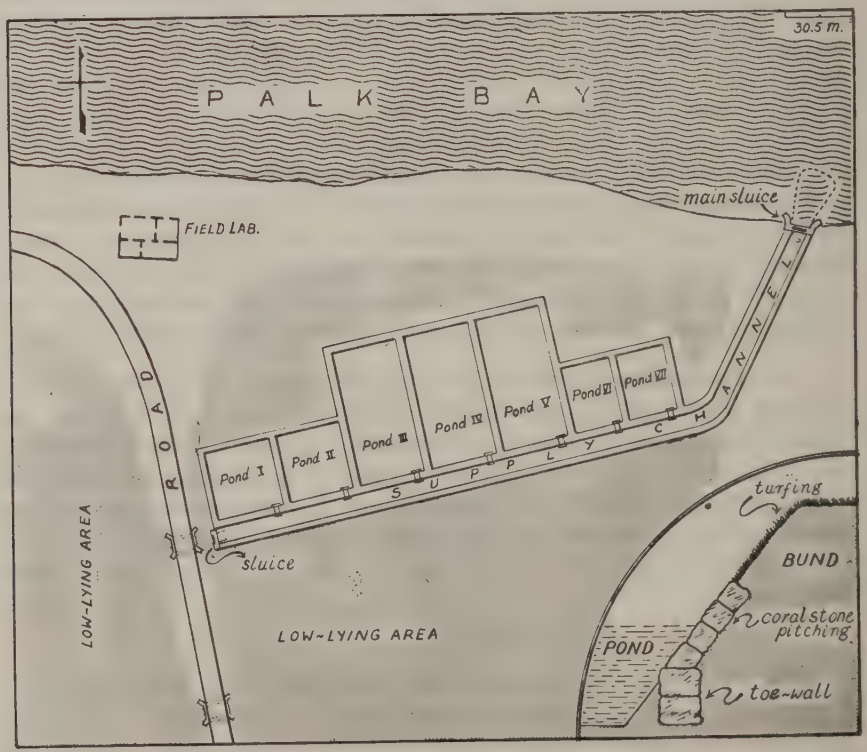


FIG. 1. General outlay of the experimental marine fish ponds. The inset shows one half of a bund in section.

toe-wall, also of coral stones. This has been found to be helpful in preventing the constant silting and caving in of the bunds at the water-level and thereby minimising the cost of labour in maintenance. As an additional protection the surface of the bunds above this is covered up with turfing because it has not been successful in stabilising the surface otherwise by means of sand-binding plants owing to the highly saline nature of the soil.

The dimensions of the seven ponds are as given in Table I.

TABLE I

Pond No.	Length (meters)	Breadth (meters)	Av. depth (meters)	Water area (sq. meter)
I	30·5	30·5	0·5	930
II	30·5	30·5	0·5	930
III	61·0	30·5	1·0	1860
IV	61·0	30·5	1·0	1860
V	61·0	30·5	1·0	1860
VI	30·5	22·0	0·5	700
VII	30·5	22·0	0·5	700

It might be mentioned here that the pond system is not organised into separate nurseries and rearing ponds and for purposes of experimental convenience the different tanks are also not interconnected Complete drainage of the ponds using only the tidal flow is also not possible in the existing system because of the low elevation of the land from the mean sea level and the poor tidal amplitude in this region of the coast.

Some of the ecological characteristics of the area which exert their influence on pond life have been discussed in an earlier paper by the author (1959). The pattern of annual fluctuations in characteristics of the water in the ponds as indicated in Fig. 2 largely reflects the changes in the surrounding lagoon. The surface temperature in ponds is highest (32°–33° C.) during the summer months of March to May. A lowering of the temperature takes place during the next few months followed again by a slight rise in August to September. Thereafter there is a drop with the commencement of the monsoon and the temperature remains low through the succeeding months

until the beginning of the next summer. The salinity usually remains above 30‰ and towards the latter half of the summer period until the beginning of the monsoon the water becomes hypersaline attaining a value around 45‰. Periodical replenishments of water from the sea minimises extreme increase in salinity during this part of the year when evaporation is at its maximum. pH is more or less steady throughout the year, remaining

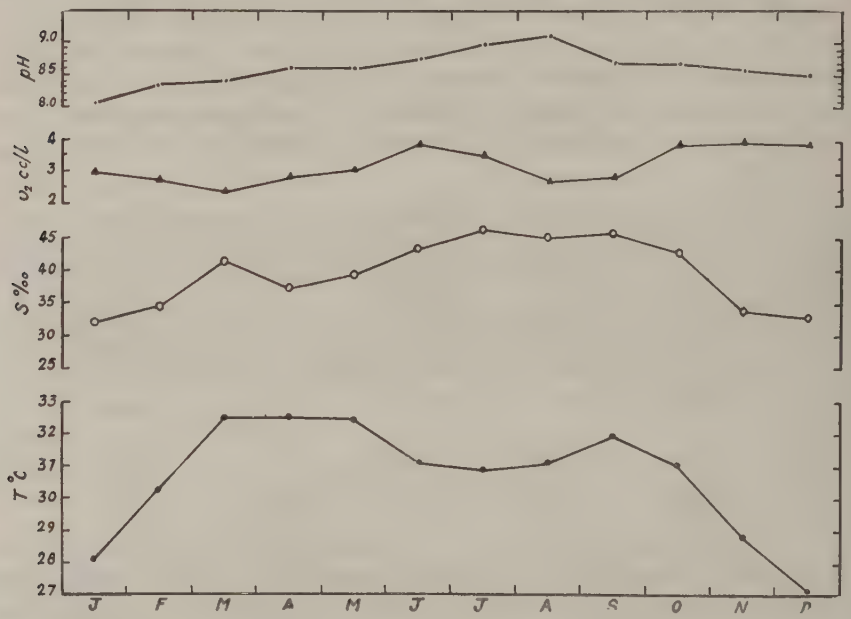


FIG. 2. Graph showing the pattern of annual fluctuation in temperature, salinity, dissolved oxygen and pH of the water in the experimental marine fish ponds.

between 8·1 and 8·6. Dissolved oxygen shows an average value of 3·0 ml./l. and often fluctuates between 2·0 and 5·0 ml./l. The highly silt-laden nature of the mud increases the inorganic suspension in the water during the severe winds and often limits the Secchi disc reading between 40 and 70 cm. at midday. The water becomes clearest after the monsoon when much of the suspended matter tends to settle down. The levels of total and inorganic phosphorus in the water remain around 60·0 mg.P/l. and 5·0 mg.P/l. respectively throughout the major part of the year. Compared to the more open lagoon or the sea-water these values might be said to be somewhat higher. Information on other nutrients are not available at

present. Similarly any detailed analysis of the mud in the ponds has not been carried out beyond obtaining an ave age value which shows a low organic content indicated by a loss of 12·4% on ignition. The phosphorus and nitrogen values are of the order of 0·033% P/m³ and 0·35–0·46% N m³.

A variety of diatoms, chief among which are Pleurosigmoids, Naviculoids and Nitzschioids, occur throughout the year. Besides these many other marine species also find their way into the ponds along with the seawater but do not constitute a permenent feature of the plankton. The blue-green algæ belonging to the genera *Phormidium*, *Microcoleus*, *Lyngbia* and *Spirulina* also are major constituents while small amounts of *Chætomorpha* can be seen growing attached to stones and the sluice embankments. Higher forms of seaweeds have been introduced into some of the ponds where they have begun to colonise. Swarms of Peridinians occur in these ponds during early summer periods and similarly some amount of sulphur bacteria ha also been noticed near the bottom of the ponds at this part of the year. The chief constituents among the zooplankters are the copepods, particularly the calanoids and harpacticoids. Besides these, nauplii of copepods and barnacles, larvæ of decapods and also mysids are important. Mention may also be made of polychæte and veliger larvæ, nematodes and a few ciliates. The composition of the plankton varies considerably during different periods of the year and the detailed analysis is not given in this account. Nevertheless, it should be pointed out that the period following the monsoon and before the summer shows the maximum standing crop.

Preparation of Ponds, Fish Collection and Experimental Stocking

Pillay (1956) in his analysis of mud from these regions had pointed out that the surface layers are relatively rich in organic matter and nutrients. However, during excavation most of this nutrient-laden soil has been removed and a compensation for this loss has been the first step in the preparation of the ponds for initial stocking of fish. A compost prepared out of seaweeds and cow-dung in equal proportion by wet weight is uniformly broadcast on the surface of water. Both seaweeds and cow-dung are available locally in large quantities and their composting in pits is also an easy process. A treatment with 500 pounds (wet weight) of compost per acre of water area in the initial stages has been necessary while after the first two treatments at monthly inte vals this might be advantageously reduced to nearly one-fourth the quantity. A slight increase in the pH of the water of the order of 0·3 might occur following the application of this compost but this condition normally corrects itself in the course of about

ten days. Although the initial stocking of the ponds with fish is deferred for a fortnight after the treatment with compost it appears that the fish are not affected during subsequent manuring. The significance of this type of compost manure in increasing the biological productivity of saline waters has been discussed by Pillay (1955). Besides this occasional use of green manure (locally available plants for this purpose are *Thephrosia* and *Pithecolobium*) has also been helpful. The water in the ponds invariably shows a noticeable effect as indicated by a change in colour almost within a week after these treatments. An increase in phytoplanktonic organisms, predominantly the Myxophyceæ and the diatoms, seems primarily responsible for this change in colouration. Changes are also observed at the bottom of the pond and the mud shows a layer of greenish scum consisting of blue-green algæ, diatoms and sometimes rich bacterial flora. Analysis of the chemical cycle undergone at various stages of manuring and other critical results of manuring experiments will be published in due course. The use of chemical fertilizers has not so far been attempted in these ponds. Sulit *et al.* (1957) claim to have used commercial fertilizers to economic advantage in the preparation of *Chanos* nursery ponds in the Philippines.

Very few aquatic organisms injurious to fish are found to thrive in these ponds. Midge larvæ (*Chironomus*) have been reported to be a serious pest in the milkfish ponds of Taiwan (Tang and Chen, 1959) who have also pointed out the paucity of these pests during season of high salinity. The usually high saline environments of the ponds should be responsible for such absence of some of the common pests. However, the problem of predatory fish finding their way into these ponds has been a serious one which has not been satisfactorily solved. Among others which cause damage to the fish are the Portunid crabs and the numerous avian predators.

Chanos fry from 15 mm. onwards up to fingerlings of about 120 mm. are obtainable in large numbers from the surrounding lagoon throughout the months of March to July. For these culture experiments, however, only fingerlings have been made use of and these are collected by means of the *konda valai* (a rectangular strip of net with spreader sticks at intervals). The entire requirement of fingerlings for stocking the ponds is collected from the immediate vicinity which minimises problems of their transport and this unique advantage the location of the farm enjoys may specially be pointed out. Soon after collection the fingerlings are carried to the ponds and retained in velon net boxes or cloth hapas before they are carefully sorted out and released into the ponds.

The rate of stocking of the ponds has guided some earlier trials according to which the ponds were stocked at two density levels of 2,500 and 5,000 fingerlings (of 80–100 mm. length) per acre of water surface. While a high rate of stocking may not be justifiable for these waters whose biological productivity is low, factors such as the loss due to predation and the consequent low survival of the fish had to be taken into consideration. The rate of 500–3,000 fish per hectare adopted by the fish growers of the Eastern countries as given by Schuster (1958) does not seem to be applicable to the present local conditions.

Growth of Fish, Survival and Yield

Chanos fingerlings with an average length of 80 mm. at the time of stocking attained a length of 300 mm. at the end of one year in these ponds. Figure 3 indicates the growth pattern of the fish in these experimental tanks from which it may be seen that the progress is relatively rapid during the

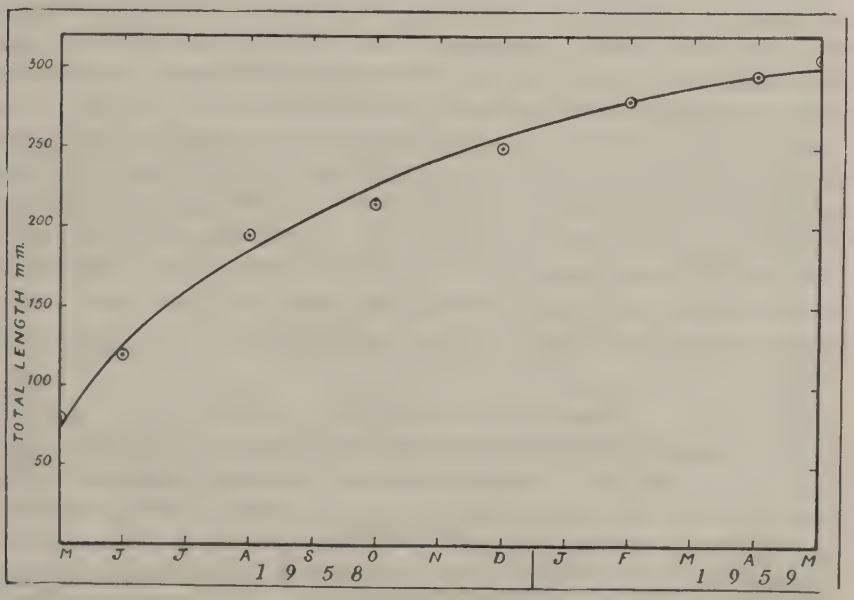


Fig. 3. Growth of milkfish (*Chanos chanos*) in ponds during the twelve months from May 1958.

first three or four months. In the marine fish ponds in Krusadai Island (Madras State) Chacko and Mahadevan (1956) have reported that fish of

50–85 mm. in average length attained 235 and 240 mm. respectively at the end of twelve months. The results obtained in our preliminary experiments are by no means comparable to those that have been produced elsewhere, particularly in the East Asian countries where the conditions are extremely different. Even in those regions widely different rate of growth has been observed depending on the type of ponds in which the fish are cultured. Schuster (1958) has summarised the influence of the various factors such as availability of food and space, salinity and temperature on the growth rate of *Chanos* which reveals the complicated nature of the problem.

The ultimate survival of *Chanos* in these experimen al tanks varied from 9–11%. The survival during the different months have not been ascertained but it is believed that the loss has been greatest during the early phases following stocking. Apart from any natural mortality the loss due to predation by birds and fish (mainly *Elops* and *Therapon*) has been largely responsible for bringing the survival to such a low level. While discussing the question of improving the survival rate of fish under cultivation, Schuster (1958) gives a wide range from 20–80% from place to place depending on the care bestowed and, among other factors, has specially pointed out the possible loss due to predators.

Under the conditions described above, the yield of fish obtained in the different ponds during the experiment of 1958–59 varied between 212 and 455 kg. per hectare (195 and 405 pounds per acre). Figures on the average annual production from the different regions of the Indo-Pacific available from reliable records show great variations and up to nearly 2,000 kg. of fish per hectare has been reported in the ponds in Taiwan where heavy manuring and artificial feeding of fish has been resorted to (Tang and Chen, 1957).

Discussion

The primary object of this report is to indicate the fish culture potentialities of an area that is usually regarded as an inferior biological environment. Apart from the poor and porous soil which is largely responsible for inhibiting the fertility of the ponds and for increasing the labour involved in maintaining the bunds, the possible danger of high water-levels during some years imposes certain practical problems. This might enhance the capital outlay of the scheme as it did in the present attempt. Lack of a source of freshwater supply in the immediate vicinity also can be a handicap although the increase in water salinity in the ponds during summer periods can be minimised with improved sea-water supply systems.

In so far as the possible fish production in the ponds are concerned the data obtained from the present experiments show a several fold increase from the natural yield from the region (Tampi, 1959). Even this value of about 400 pounds of fish per acre is admittedly low, but considering the effort spent in attaining this increase the prospects for further improvement in results are evident.

Besides the actual output of fish there are other factors that are significant while considering a marine fish farm in this area on an economic basis. The area in question is an excellent collection ground for milkfish and mullet fingerlings during definite seasons of the year and would therefore justify the establishment of a centre for salt water fish fry trade. This can constitute an important subsidiary industry. Accessibility of the place by road and sea and its proximity to rail road communication increases facilities for fish transport. The occurrence of *Nematalosa nasus* in sufficient numbers in this area and the possibilities of utilizing such less exploited species for culture work are also to be explored. Its ability to withstand wide environmental changes and the fact that the fish has been observed to breed in ponds deserve special mention in this connection as only few species in the tropics are known to breed in confined waters. In the practical management of the farm, availability of cheap organic manure in the form of seaweeds washed ashore in immense quantities also would be of considerable advantage. Lastly, it must be said that in some kind of co-operative management where collective effort is possible the initial outlay of an extended project of this type can be substantially minimised with the extremely low cost of land in this region and can therefore be worked out on a profitable level.

Summary

The first results of marine fish culture experiments in Mandapam are reviewed here indicating the possible means of increasing the yield of fish in a region that is normally a poor biological environment. The drawbacks as well as the advantages in organising a marine fish farm scheme in this locality are briefly discussed.

References

Chacko, P. I. and Mahadevan, S. 1956 — Collection and culture of milkfish *Chanos chanos* (Forskål) in and around Krusadai and Rameswaram Islands, with notes on its biology. *Fish. Stn. Reports and Year-Book*, April 1954 to March 1955. Department of Fisheries, Madras, 145–55.

Pillai, V. K. 1955 .. Utilization of natural by products for the cultivation of blue-green algæ. *Curr. Sci.*, **24**, 21–23.

Pillai, V. K. 1956 .. Chemical composition of lagoon muds. *Proc. Indian Acad. Sci.*, **44**, 130–36.

Schuster, W. H. 1958 .. Synopsis of biological data on milkfish *Chanos chanos* (Forskål). *IPFC 8th Session*, Colombo C58/WP 25 (mimeo.).

Sulit, J. I., Esguerra, R. S. and Rabanal, H. R. 1957 Fertilization of bangos nursery ponds with commercial fertilizer. *IPFC 7th Session*, C57/Tech. 12 (mimeo.).

Tampi, P. R. S. 1959 .. Ecological and fishery characteristics of a saline lagoon near Mandapam. *J. Mar. biol. Assn. India*, **1** (2), 113–130.

Tang, Yun-an and Chen, T. P. 1957 The use of chemical fertilizers in the milkfish ponds of Taiwan. Chinese-American Joint Commission on Rural Reconstruction. *Fish. Ser. No.* 3, 1–20.

————. 1959 .. Control of Chironomid larvæ in milkfish ponds. *Ibid.*, No. 4, 1–36.

A STUDY ON MATURITY AND SPAWNING OF *POLYDACTYLUS INDICUS* (SHAW)

By P. S. Karekar and D. V. Bal

(*Institute of Science, Bombay*)

Introduction

A general survey of the literature on biology of marine fishes of India shows that good deal of work has been done on aspects like food and feeding habits, development, occurrence, etc. Similarly the study of maturity and spawning activities of fishes of commercial importance has been receiving attention of Indian workers in recent years. Palekar and Karandikar (1950, 1952 and 1953) by using ova diameter as the basis, have roughly demarcated spawning period of *Eleutheronema tetradactylum* (Shaw), *Thrissocles purava* (Ham.) and *Coilia dussumieri* Cuv. & Val. Contributions of Prabhu (1950, 1955 and 1956) have also supplied useful information on the maturation of *Trichiurus haumela* (Forsk.) and several other fishes based mainly on the study of intra-ovarian eggs. Similar investigations carried out by Pradhan (1956) on Mackerel, Sarojini (1957) on Grey Mullet and Krishnamoorthi (1958) on Spotted Seer have helped in determining the extent of the spawning season and fecundity in these fishes.

As could be seen from the literature, the Biology of *Polydactylus indicus* (Shaw), an important food fish of Bombay, has not been worked out in detail. Some information in this connection is, however, available from the papers of Chacko (1949) and Mohamed (1955). The present paper relates to an account of the condition of the ovary, developmental history of ova, duration and frequency of spawning season, fecundity and determination of minimum size at maturity of *P. indicus*.

Material and Methods

During the period of this investigation, extending from August 1952 to October 1954, average 30 specimens per month were examined from the fish landed at the Prince's Docks, Bombay, by the trawlers operating off Kutch and Bombay. However, the data presented in this paper in tabular forms and graphs refers only to 669 specimens examined during the period August 1952 to June 1953. After noting the weight and length, the ovaries

were hardened in 5% formalin. There was no appreciable shrinkage or swelling of the ova due to preservation in formalin.

The samples of ova from anterior, central and posterior regions of the preserved ovary were teased on a slide and from each sample the diameters of 75 ova were measured by means of micrometer eye-piece. It was found that the ovaries in all stages of development contained ova 0·20 mm. or smaller in diameter throughout the year and hence it was decided to record the diameters of ova larger than 0·20 mm. in diameter which is the largest one for an immature ovum. Clark (1934) and de Jong (1938) have found this method to give satisfactory results. The procedure for the fecundity study was as follows: excess of moisture from the ovaries sufficiently hardened in formalin was drained off and a gram sample of the ovary taken and the number of ova larger than 0·20 mm. in diameter was counted. The number of ova in the maturing state was ascertained from the diameter measurements of the same ovary sample and ova production computed for the whole ovary.

Description of the Ovary

The ovary cannot be easily distinguished in a specimen below 50 cm. in length. The immature ovary appears like a thin short whitish ribbon lying close to the air bladder. The tiny immature ova are invisible to the naked eye and appear as transparent cells, each with an elliptical outline and a large nucleus.

As the ovary passes from the immature to the maturing stage, it turns yellow and becomes conspicuously thickened on all sides. The maturing ovary has been noted from fish measuring 72·0–105·0 cm. in length and varying within a wide range of 15·0–300·00 gm. in weight. The maturing ova appear as rounded, yellowish, opaque cells, measuring from 0·21–0·70 mm. in diameter.

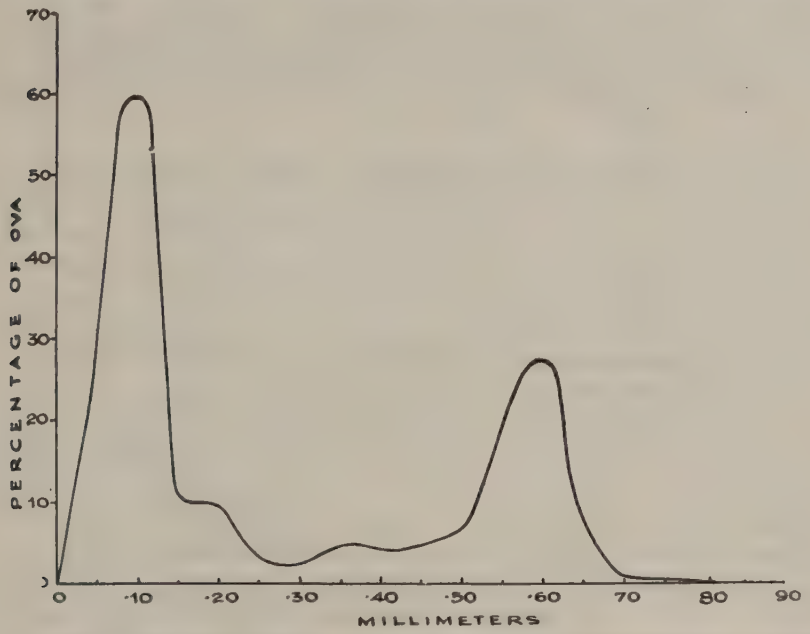
During the course of the present study only a small number of specimens with mature ovaries was noted. They varied from 72·0–105·0 cm. in length, their ovaries weighing from 300·0–450·0 gm. The mature ovary appears like a yellow bag of cellophane paper, containing large mature ova in addition to the immature and maturing ones. The mature ova vary in diameter from 0·70–0·87 mm.

The ovary, after extrusion of the mature ova, appears like a blood shot, wrinkled, collapsed sac, with leathery wall in contrast to the thin parchment like wall of the distended ripe ovary. Closer examination of such

a spent ovary reveals the presence of a few scattered mature ova along with well advanced maturing ova or a few mature ova with the immature ones.

Development of Ova

In order to classify the ova into various stages of maturation, diameter measurements of a sample consisting of 840 ova from an advanced maturing ovary was made. Frequency polygon of these measurements made at random roughly shows four groups of ova (Text-Fig 1). The first group up to



Text-Fig. 1. Frequency polygon of the diameters of 840 ova measured from a maturing *P. indicus*, 83·20 cm. in standard length.

0·15 mm. in diameter which is present in the ovary throughout the year, represents immature eggs. The second group, between 0·15 and 0·30 mm., comprises opaque, creamy eggs, found in most of the adult females all the year round. The third group of ova, between 0·30 and 0·45 mm., is also opaque and creamy white in colour. The fourth group between 0·45 and 0·70 mm. includes more yellowish, glistening eggs with vacuolated yolk, in the penultimate stage of maturation.

If all *P. indicus* matured at the same time, the growth of ova to maturity could be easily traced, but the state of maturity varies greatly among indi-

viduals with the result that fish in all stages of maturity are found in one sample. Because of this diversity among individuals, collected at the same time, the data could not be arranged in a chronological order to show various stages of maturity. The data are therefore grouped according to location of the largest mode in the diameter frequency percentages of eggs from each fish.

In studying the growth of the ovary from the immature to spent stage, ova diameter measurements were made in different stages of maturity. The average ova diameter frequency percentages are presented in the form of polygons and number of fish included in each polygon is indicated thereon. All the frequency polygons resolve into the following 14 stages of matuiity:

Immature:

Stage '*a*' frequencies with a mode between 0·06 and 0·10 mm. only.

„ '*b*' „ „ 0·11 and 0·15 mm. „

„ '*c*' „ „ 0·16 and 0·20 mm. „

Maturing:

Stage '*d*' frequencies with last mode between 0·21 and 0·25 mm. only.

„ '*e*' „ „ 0·26 and 0·30 mm. „

„ '*f*' „ „ 0·31 and 0·35 mm.

„ '*g*' „ „ 0·36 and 0·40 mm. „

„ '*h*' „ „ 0·41 and 0·45 mm. „

„ '*i*' „ „ 0·46 and 0·50 mm. „

„ '*j*' „ „ 0·51 and 0·55 mm. „

„ '*k*' „ „ 0·56 and 0·60 mm. „

„ '*l*' „ „ 0·61 and 0·65 mm. „

Mature:

Stage '*m*' frequencies with last mode beyond 0·71 mm.

Spent:

Stage '*n*' frequencies with ova larger than 0·20 mm. but in a degenerating stage.

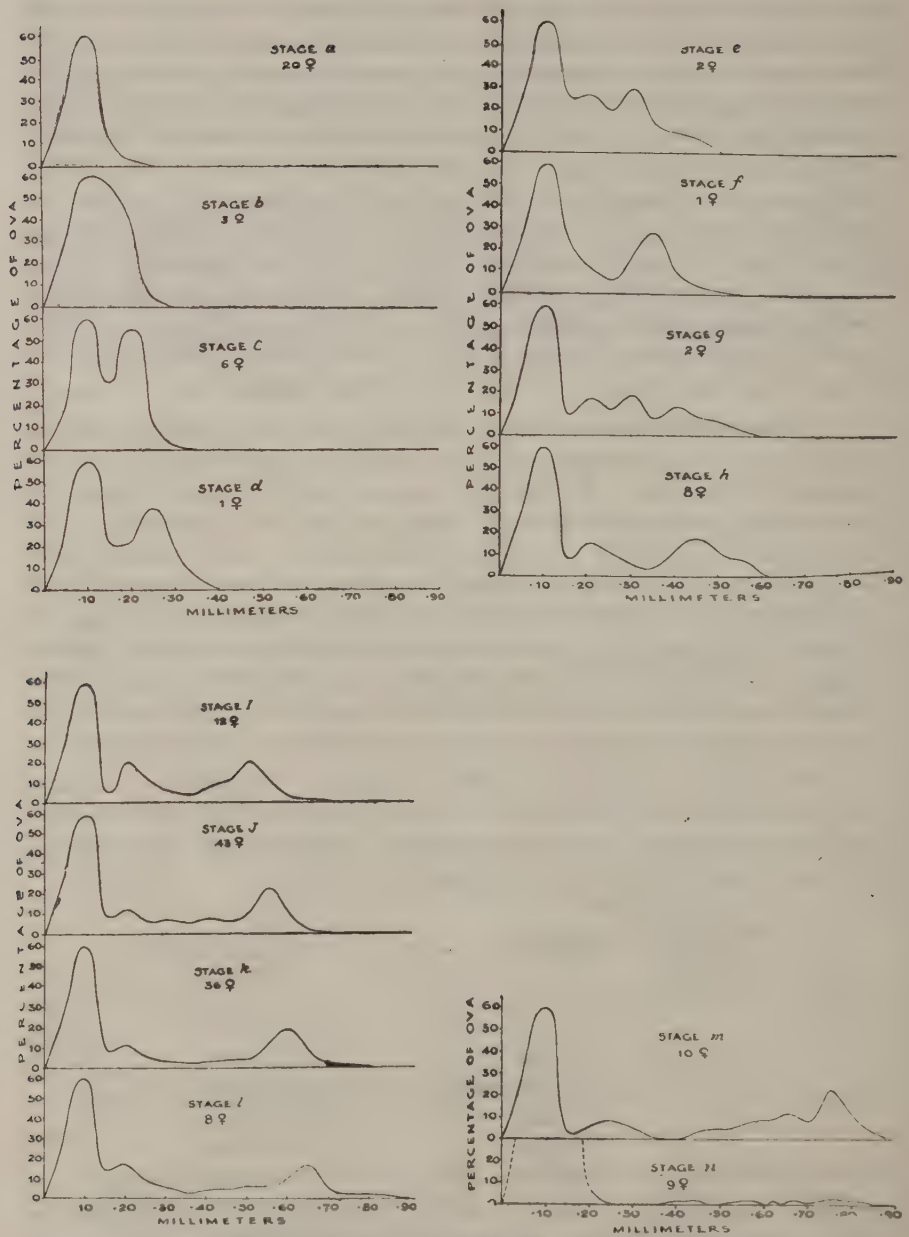
Stage '*a*' shows the modal point at 0·10 mm. which persists in all the subsequent stages. The curve in stage '*b*' is little broadened indicating

an increase in size of ova from the immature group. In stage '*c*' an additional mode makes its appearance at 0·20 mm. In stage '*d*' this mode has shifted on to 0·25 mm. indicating the growth of some immature ova into maturing stage. By the time the first batch of eggs has increased in size sufficiently to develop a definite mode at 0·30 mm. in stage '*e*', a second batch of maturing eggs is suggested by the slight bulge in the curve at 0·20 mm. This second batch seems to merge into the first in stage '*f*'. In stage '*g*', besides the last mode at 0·40 mm., two additional modes become apparent, at 0·20 and 0·30 mm., respectively. Out of these two succeeding batches, the smaller one retains its identity whereas the advanced one merges into the first batch with the resulting mode at 0·45 mm. in stage '*n*'. From stage '*i*' onwards there appears to be a distinct separation between the two groups with their modes at 0·20 and 0·50 mm. respectively.

The last mode moves on from 0·50–0·55 mm., 0·60 and 0·65 mm. in stage '*j*' and '*l*' respectively, while the preceding mode practically remains stationary at 0·20 mm. It, therefore, appears that the growth rate of the first maturing group of ova is a little faster than that of the succeeding group until stage '*j*' is reached. In stage '*k*' and stage '*l*' the first group seems to grow more rapidly than the second, with the result that it practically gets separated from the second in stage '*l*'. The rate of growth from stage '*j*' to stage '*l*' so that, by the time first batch of eggs becomes mature, there is one more batch almost ready for maturation or in penultimate stage. These maturing eggs belong to the second batch of eggs which may mature in the same season or may be held over till the next season or may disintegrate.

The various stages of maturity indicated by frequency polygons may conveniently be condensed so as to correspond with the standard maturity scale adopted by the international council for the exploration of the sea (Wood, 1930) as given below (Text-Fig. 3):

International council scale	Stages in *p. indicus*	Ova diameter range (mm.)
I	'*a*', '*b*' and '*c*'	0·00–0·20
II	'*d*' and '*e*'	0·21–0·30
III	'*f*', '*g*' and '*h*'	0·31–0·45
IV	'*i*' and '*j*'	0·46–0·55
V	'*k*' and '*l*'	0·56–0·70
VI	'*m*'	0·71 mm. onwards
VII	'*n*'	Ova larger than 0·20 mm. but degenerating



TEXT-FIG. 2. Ova diameter frequency polygons showing the growth of ova to maturity.

According to this regrouping, stage I includes all the fish with immature ovaries containing small, tran parent eggs. Stage II to IV comprise fish with progressively fuller ovaries in which eggs are clearly discernible to the naked eye, but are still opaque. Stage V groups all those fish which have fully extended ovaries containing larger eggs ready for transformation into mature eggs. Stage VI includes mature fish with the transparent eggs and those which are actually 'running'. Stage VII comprises spent fish with empty and flaccid ovaries.

Spawning Season

On the basis of the observations made by Hickling and Rutenberg (1936); Walford (1932); de Jong (1939) and others the spawning activity in fishes may be classified into the following four categories:

Category '*A*'.—Spawning taking place only once a season during a short period of definite duration. In fishes belonging to this category, the mature ovary contains mature ova distinctly separated from the immature egg stock.

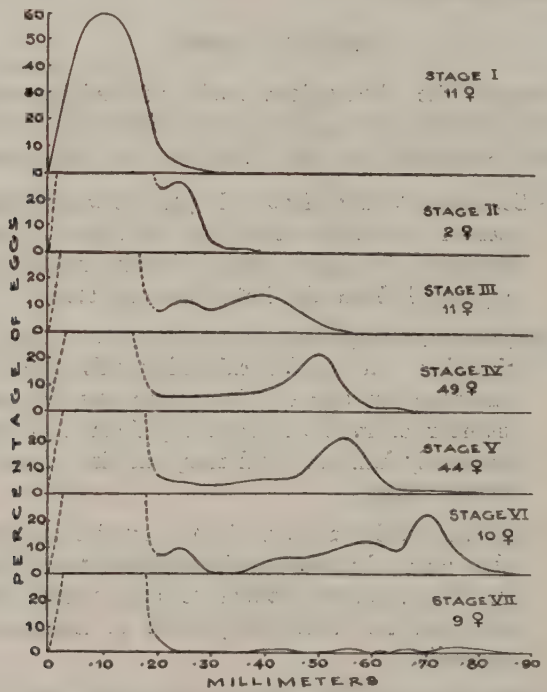
'*B*'.—Spawning taking place only once a season, but with a longer duration. In species exhibiting this type of spawning, the range in size of the mature ova, irrespective of the number of modes representing them, has been found to be nearly half the total range in size of the entire intra-ovarian eggs.

'*C*'.—Spawning twice a year. In the ovaries of fishes exhibiting this type of spawning, in addition to the batch in ripe condition, another batch of eggs which has undergone more or less half the process of maturation, becomes apparent.

'*D*'.—Spawning extended over a long period, but intermittently. Here the different batches of eggs in the ovary are not sharply differentiated from one another, thereby indicating that the passing of one batch of eggs into the next stage is a continuous process.

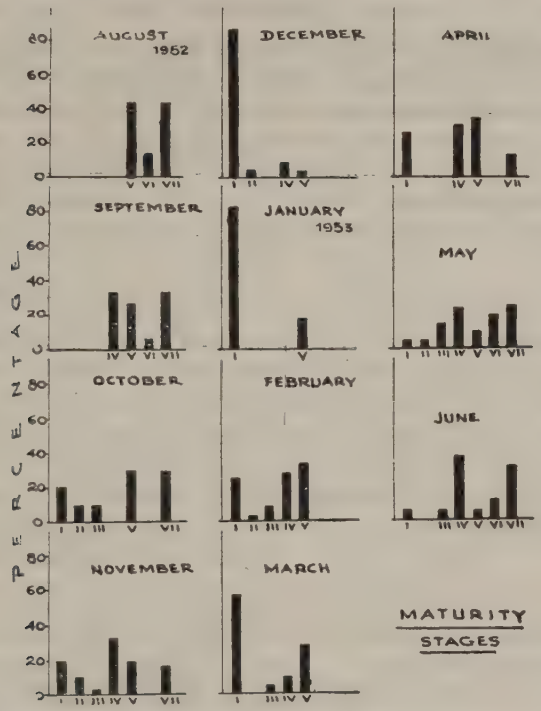
In the light of the data in hand, *P. indicus* appears to belong to category '*D*'. The important factor contributing to the prolonged spawning activity in this fish is maturation of intermittent batches of eggs that are spawned during the extended period, the exact duration of which is not known. Mature translucent eggs appear in the ovary distributed irregularly among

the still maturing, yellowish opaque eggs in earlier stages of development. These mature ova are dehisced into the lumen of the ovary which on superficial examination, shows very few mature ova, in comparison with the total extruded ova. The presence of these mature eggs in the ovary in smaller or larger numbers, over a major period of the year coupled with the 'Plumpudding' condition of the ovary, indicated that the final phase of maturation is a continuous process in *P. indicus*.



TEXT-FIG. 3. Ova diameter frequency polygons showing the growth of eggs to maturity.

In the absence of any definite information on eggs, larvæ and post-larvæ of *P. indicus*, the data on the frequency percentages of stages of maturity, as shown by histograms (Text Fig. 4), seem to corroborate the earlier inference of prolonged spawning. It is evident from this data that the fifth or penultimate stage is present in most of the months of the year. As has been already pointed out, the advanced maturing ova in stage V take a short time to reach stage VI. The individuals in stage V found in all months would, therefore, spawn in a short time and thus contribute towards prolonged activity. Besides, the spent individuals occur during the month



TEXT-FIG. 4. Percentage composition of various stages of maturity of *P. indicus* from month to month.

of April to November. The presence of very high percentage of fish in stage V and also of spent fish in August and September indicate peak spawning activity during this period. The prevalence of all stages almost throughout the year suggests that there is continuous addition of mature individuals to the fish population in order to carry on spawning activity (Table I).

FREQUENCY OF SPAWNING

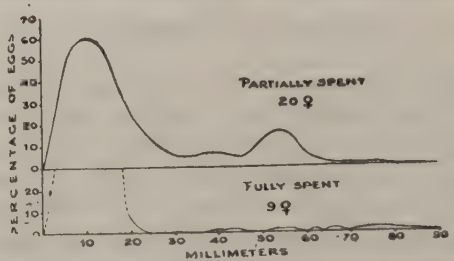
The multiplicity of modes in the percentage frequency curves of ova diameter suggests that individuals of *P. indicus* may spawn more than once during a spawning season. In support of this it will have to be shown that the secondary modes do not include eggs which will never ripen, but will degenerate and be reabsorbed at the close of the spawning activity. In the present study, two types of ovaries with superficial appearance of a spent ovary were encountered. Careful examination and ova diameter frequency

TABLE I

Percentage composition of various maturity stages of P. indicus *during the period August* 1952 *to June* 1953

Month	Maturity stages						
	I	II	III	IV	V	VI	VII
August 1952 ..	..	..	..	..	42·8	14·4	42·8
September ..	..	..	..	33·3	26·6	6·8	33·3
October ..	20·0	10·0	10·0	..	30·0	..	30·0
November ..	19·0	9·5	2·3	33·2	19·0	..	16·0
December ..	85·7	3·5	..	7·0	3·5	..	..
January 1953 ..	82·3	..	..	..	17·7	..	..
February ..	25·0	3·1	9·3	28·1	34·3	..	..
March ..	57·1	..	4·7	9·4	28·5	..	..
April ..	25·0	..	..	29·2	33·3	..	12·5
May ..	4·7	4·7	14·1	23·8	9·4	18·8	23·8
June ..	5·6	..	5·6	37·1	5·6	16·8	30·8

polygons of these ovaries reveal the apparent difference in the two (Text-Fig. 5). In one there are very few mature eggs, but the last mode in the maturing eggs is in advanced stage, that is beyond stage IV or V suggesting that these eggs are destined to mature in the same season. On the other hand, in the second type of ovary, the last mode is situated not beyond



TEXT-FIG. 2. Ova diameter frequency polygons of partially and fully spent *P. indicus*.

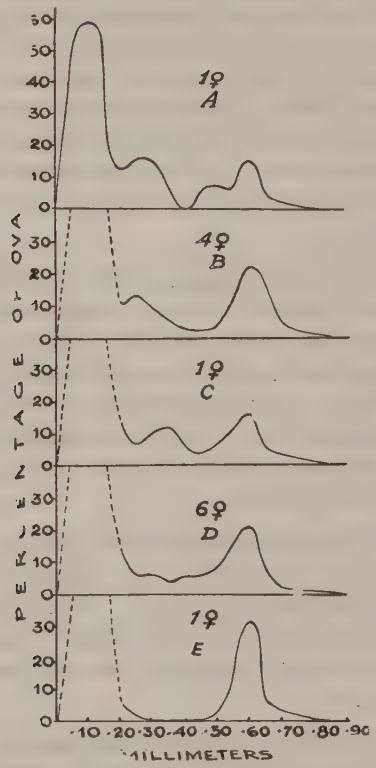
0·30 mm. diameter, clearly demonstrating separation of early maturing and very few mature ova. The first type, therefore, represents ovary which has at least extruded one batch of its mature ova and is going to continue spawning, while the second type of spent ovary has extruded all its batches of mature ova. As the advanced maturing eggs occurring in the first type or partially spent ovary would require half the time necessary for immature eggs to grow to maturity (de Jong, 1939) the subsequent spawning would take place within a short time. The presence of these two types of ovaries leads to an inference that the individual *P. indicus* spawns at least twice in the same season.

The percentage frequency polygons of the maturing ovaries (Text Fig. 2) seem to indicate that *P. indicus* spawns in intermittent batches. However, the polygon of the mature ovaries (stage '*m*') shows a distinct separation between the early maturing and the advanced maturing and the mature ova. This separation tends to show spawning at a time is of short duration; but the polygon representing the partially spent condition (Text-Fig.5) appears to account for this separation, since the gap is presumably filled up by the following group of maturing ova.

In order to trace the successive batches of ova spawned by an individual it would be interesting to compare ova diameter frequency percentage polygons of ovaries belonging to stage V. These curves give the average frequency percentage of females in stage B arranged serially according to their stage of maturity. The number of fish represented by each curve is indicated in Text-Fig. 6.

In curve 'A' four distinct modes in the immature and maturing stock of ova at 0·10, 0·25, 0·45 and 0·65 mm. are exhibited. Out of these four batches of eggs, the batch represented by the modal group at 0·10 mm. is present in all ovaries in stage V, all the year round, whereas the remaining three modal groups represent three batches of eggs maturing one after the other. The last batch with mode at 0·65 mm. is ready for spawning and the successive batches would follow after a certain time interval. After spawning of the batch in advanced stage of maturation, the state of the ovary is as represented in curve 'B' where two modes at 0·25 and 0·60 mm. indicate the remaining two batches undergoing maturation. In curve 'C' the mode at 0·25 mm. has shifted to 0·35 mm. while the last one remains at 0·65 mm. The last crop is spawned out and only one batch of maturing eggs is left for spawning as seen in curve 'D'. As would be expected in the next phase of ovary, as shown in curve 'E', there is complete separation of the immature stock of ova from the maturing ova in advanced stage of

maturation. This indicates close of the spawning for that particular individual during that spawning season.



TEXT-FIG. 6. Ova diameter frequency polygons of females in stage V arranged serially according to their state of maturity.

Thus the above observation seems to suggest that during the spawning season, at least three batches of ova mature in succession and are extruded one after the other at a certain interval of time over a prolonged period. The inference regarding the prolonged spawning is also supported by the observation made by Foulton (1899), in that the presence of intermediate group of ova in large number is associated with the prolonged spawning seasons.

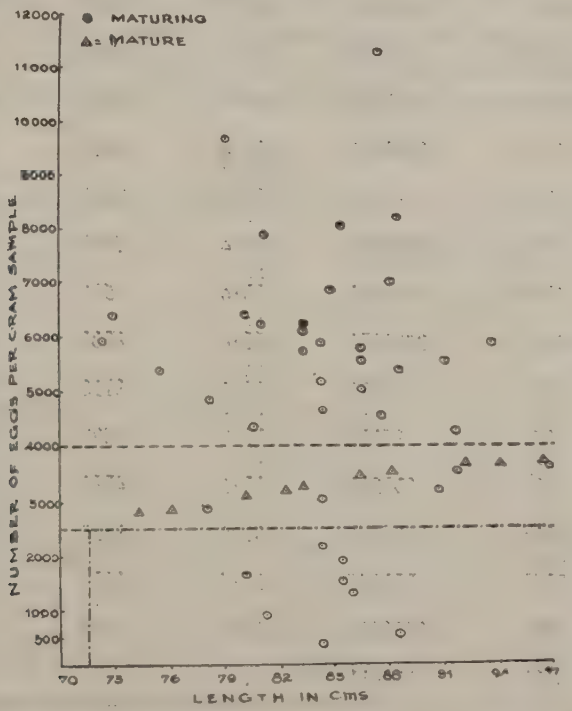
FECUNDITY

In order to study the total production of eggs per individual, about 40 maturing and 10 mature specimens of *P. indicus* were examined. As

the actual number of ova produced by an individual cannot be correctly estimated in the absence of definite knowledge of the number of batches spawned during the season and the time between successive spawnings, the data of ova count in one gram sample for each individual has been used to estimate number of ova that will mature. Nevertheless, the ova count per gram sample of the maturing ova gives a rough estimate of the potential stock of the ovary irrespective of the number of batches it has spawned.

The data regarding ova count in one gram sample and estimated ova in maturing ovaries is presented in Table II. The number of ova produced by the individuals of the same length at times show discrepancies, because it is likely that some individuals are ready for spawning for the first time in the season, while others may have already spawned one or two batches of ova. The small number of maturing ova in a few cases might be due to the recurring maturation having commenced and hence a stock being developed for spawning in the next season.

The Text-Fig. 7, Table II, represents ova count per gram sample of ovary of maturing and mature *P. indicus*, of various lengths. The number of



TEXT-FIG. 7. Number of eggs per gram sample of ovary of *P. indicus* of various lengths.

TABLE II

Number of maturing eggs in P. indicus *in sizes ranging from* 72·3–96·7 *cm. in standard length*

Length cm.	Ova count in one gm. sample	Estimated ova	Length cm.	Ova count in one gm. sample	Estimated ova
72·3	5958	929510	84·7	6863	3706543
72·8	6419	2311146	85·3	1515	93979
76·9	5396	2212417	85·3	1881	231363
78·1	4880	390432	85·3	8082	1842885
78·0	2860	1029600	85·8	1302	109401
79·0	9675	5611650	86·3	5563	745490
80·1	6429	3394945	86·3	5874	810672
80·1	1639	219643	86·3	5025	196007
80·5	4333	563362	87·4	11357	2021688
81·0	6245	3048033	87·4	4315	763820
81·1	889	85410	88·0	7019	856402
81·2	7888	2808437	88·4	5410	1006354
83·2	6159	2371449	88·4	585	55008
83·2	6263	3570029	88·4	8231	4387229
83·2	5760	1474739	90·5	3190	676280
84·2	365	36905	91·0	5577	2063490
84·2	3034	291288	91·5	4280	419469
84·2	5206	1926575	91·5	3527	2737184
84·2	2161	280965	93·6	5884	588425
84·2	5907	1453294	96·7	4109	780736
84·3	4423	119431	..	..	..

mature eggs spawned in one batch may vary between 2550 and 4000 per gram sample. As referred to above, the number of batches of ova spawned in one season may be three. To cite an example, two specimens measuring 79·0 and 87·4 cm. show their maturing stock of 9675 and 11357 eggs respectively. These two individuals, which are ready for spawning for the first time in that season, have these eggs as a potential stock which may be spawned in three batches. The individuals between 4000 and 8500 egg-lines are probably those which have discharged one or two batches of eggs, while those having potential stock of 2550–4000 eggs per gram sample, may have already spawned two batches and yet have a stock of one more batch in store. However, the individuals, with eggs less than 2550, show depleted stock of eggs and are not likely to spawn in the same season, but these would mature in the next season.

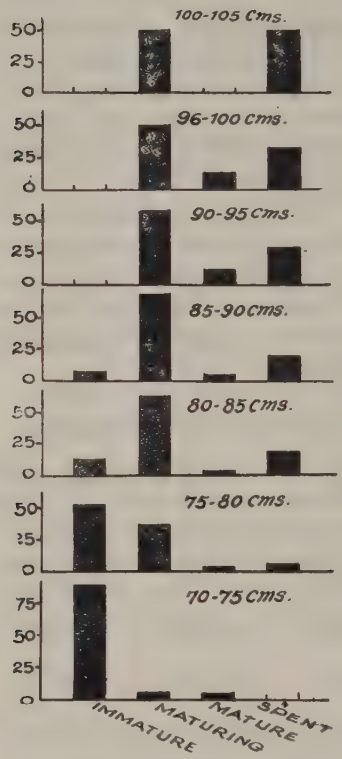
Minimum Size at Maturity

In order to determine the minimum size of maturity, the percentages of fish in immature, maturing, mature and spent stages were computed for each five centimetre length group (Text-Fig. 8, Table III). It appears from the table that the percentage of immature individuals diminishes with the increase in length and no fish above 90·0 cm. is found in an immature stage. The percentage of maturing fish increased with the length of the fish the

Table III

Percentage composition of immature, maturing, mature and spent P. indicus *in each five centimetre length group*

Length group; in cm.	Immature	Maturing	Mature	Spent
70·0– 75·0	90·48	4·76	4·76	..
75·0– 80·0	51·74	37·94	3·44	6·88
80·0– 85·0	12·67	64·56	3·79	18·98
85·0– 90·0	7·33	68·29	4·87	19·51
90·0– 95·0	..	58·82	11·76	29·42
95·0–100·0	..	50·00	16·70	33·30
100·0–105·0	..	50·00	..	50·00



TEXT-FIG. 8. Percentage of immature, maturing, mature and spent females in each five centimetre length group.

maximum being reached in the length group 85·0–90·0 cm. In the cases of mature and spent fish the percentages are in the ascending order from the length group 75·0–80·0 cm. to 100·0–105·0 cm. length group. In the length group 75·0–80·0 cm. the percentage of mature and spent individuals taken together is about 10·2, while in length group 80·0–85·0 cm. it increases to 22·6. It continues to increase in the succeeding length group, reaching a maximum of 50·0 in the 100·0–105·0 cm. group. From the data in hand, the maximum size at maturity may roughly be fixed at 80·0 cm.

SUMMARY

1. As a result of examination of 669 ovaries of *Polydactylus indicus* it was found that the diameter of immature eggs ranges between 0·0 and

0·2 mm., of maturing eggs between 0·2 and 0·7 mm. and of mature eggs from 0·7–0·85 mm.

2. Specimens measuring from 52·0–110·0 cm. and in sexual maturity stages I to V have been recorded throughout the year.

3. Studies on diameter frequency percentages of ova indicate that the individual *P. indicus* spawns more than once in a season and has a prolonged spawning season.

4. The number of mature eggs in a batch may vary from 4000–8500 and an individual probably extrudes intermittently three batches in a spawning season.

5. The minimum size at maturity appears to be approximately 80·0 cm.

References

Chacko, P. I. 1949 .. Food and feeding habits of the fishes of the Gulf of Mannar. *Proc. Indian Acad. Sci.*, **29 B,** 83–97.

Clark, F. N. 1925 .. The life-history of *Leuresthes tenuis*, an atherine fish with tide controlled spawning habits. *Calif. Div. Fish and Game, Fish. Bull.*, **10**.

————. 1929 .. The life-history of California jacksmelt, *Atherinopsis californiensis. Ibid.*, **16**.

————. 1934 .. Maturity of California sardine (*Sardina cærules*), determined by ova diameter measurements. *Ibid.*, **42**.

de Jong, J. K. 1939 .. A preliminary investigation of the spawning habits of some fishes of the Java Sea. *Treubia*, **8,** 199–218.

Foulton, T. W. 1899 .. The growth and maturation of the ovarian-egg of teleostean fishes. *Ann. Rep. fish Bd. Scot.*, **16** (3), 88–124.

Hickling, F. C. and Rutenberg, E. 1936 To ovary as an indicator of the spawning period of fishes. *J. Mar. biol. Ass. U.K.*, **21,** 311–17.

Karandikar, K. R. and Palekar, V. C. 1950 Studies on the ovaries of *Polynemus tetradactylus* (Shaw) in relation to its spawning habits. *J. Univ. Bombay*, **19,** 21–24 .

Krishnamoorthi, B. 1958 .. Observations on the spawning season and the fisheries of the spotted seer, *Scombromorus guttatus* (Bloch and Schneider). *Indian J. Fish.*, **5** (2), 270–81.

Manacop, P. R. 1936 .. The sexual maturity of some commercial fishes caught in Manila Bay. *Phillip. J. Sci. Manila*, **59,** 383–91.

Mohamed, K. H. 1955 .. Preliminary observations on the biology and fishes of the Thread-fin, *Polydactylus indicus* Shaw in the Bombay and Saurashtra waters. *Indian J. Fish.*, **2,** 164–79.

Palekar, V. C. and Karandikar, K. R. 1952 The ovaries of Bombay duck (*Harpodon nehereus*) and their relation to its spawning habits in Bombay waters. *J. Univ. Bombay*, **20,** 58–74.

Palekar, V. C. and Karandikar, K. R. 1952 .. Maturity and spawning period of *Thrissocles purava* (Ham.) as determined by ovadiameter measurements. *Proc. Indian Acad. Sci.*, **35 B,** 143–54.

———. 1953 .. Maturity of *Coilia dussumieri*, Cuv. and Val. in Bombay waters during different months of the year. *J. Zool. Soc. India*, **5,** 163–67.

Prabhu, M. S. 1950 .. On the breeding habits of the ribbon fish, *Trichiurus haumela* (Forsk). *Curr. Sci.*, **19** (7), 213–14.

———. 1955 .. Some aspects of the Biology of the ribbon fish, *Trichiurus haumela* (Forsk). *Indian J. Fish.*, **2,** 132–63.

———. 1956 .. Maturation of Intra-ovarian eggs and spawning periodicities in some fishes. *Ibid.*, **3,** 59–90.

Pradhan, L. B. 1956 .. Mackerel fishery of Karwar. *Ibid.*, **3** (1), 141–85.

Sarojini, K. K. 1957 .. Biology and fisheries of the grey mullets of Bengal. I. Biology of *Mugil parsia* Hamilton with notes on its fishery in Bengal. *Ibid.*, **4** (1), 160–207.

Walford, L. A. 1952 .. The California Barracuda (*Sphyræna argentea*). *Calif. Div. Fish and Game Fish Bull.*, **37.**

A PRELIMINARY ACCOUNT OF PRIMARY PRODUCTION AND ITS RELATION TO FISHERIES OF THE INSHORE WATERS OF THE GULF OF MANNAR

By R. Raghu Prasad and P. V. Ramachandran Nair

(Central Marine Fisheries Research Station)

Introduction

In the ecological studies of marine environments dynamics of production and the quantitative aspects of the relations involved have received special interest. Such quantitative studies of the various relationships have resulted in the familiar 'Eltonian Pyramid' which represents the layering of the community brought about by the feeding habits of different species. But due to the inevitable loss of materials at each level in the food chain the yield normally will be smaller than the supply. According to Clarke (1946) "the measurement of the ratio of yield to supply, and hence the efficiency of the formation of the yield, is therefore of great importance to the ecologist, to the conservationist, and to the farmer or fishermen, in order to ascertain whether the actual yield represents a needlessly low utilization or an over-exploitation of the area."

With this object in view investigations on the primary production of the inshore waters of the Gulf of Mannar were started in 1957 to ascertain the efficiency of the formation of the yield in this region. Preliminary experiments on the primary production were conducted at a station near the Central Marine Fisheries Research Station jetty (Prasad, Pillai and Nair, 1958) and later five more stations were selected at about 8 kilometres apart in the inshore region of the Gulf, parallel to the coast. The data obtained (two years' observations from the first station and one year's from the other five stations) are used to compute the general productivity in relation to the fisheries of this region extending from Dhanushkodi to Cape Comorin for a 10-mile belt which is normally exploited by the fishermen at present.

Various methods, both direct and indirect, are employed for estimating the production of an area. The pioneer work on the production of organic matter was done in the English Channel by Atkins (1922 and 1923) who used the changes in alkalinity and phosphate consumption for computing

production. The first really direct method of the estimation of organic matter using 'clear' and 'dark' bottles was introduced by Gaarder and Gran (1927). This technique with slight modifications was subsequently used by Riley (1938, 1939, 1941 *a* and 1941 *b*) in extensive plankton investigations. A review of all the techniques has been given by Steemann Nielsen (1952) while introducing the ^{14}C technique for the determination of carbon assimilation by the plankton algæ. Though at present it has been widely recognised that ^{14}C is the most valuable tool in the determination of organic production, in the present investigations the authors have used the 'light' and 'dark' bottle technique mainly due to lack of facilities for employing ^{14}C and also due to the fact that the investigations are in shallow eutrophic areas where the present technique is applicable.

Method

Sea-water was collected from respective stations at fixed hours in bottles thoroughly cleaned with chromic acid. Control bottles were painted dark or covered with double-layered dark cloth. Sets of such 'light' and 'dark' bottles were filled with raw sea-water from surface and depth taking care that no air-bubbles were left inside. The bottles were then suspended by 'cradles' from stands erected in the sea or from bamboo poles tied to an anchored drum. The initial and the final oxygen contents of both the bottles at the end of 24 hours were determined by a modified Winkler technique (alkaline azide method described by Dickinson as quoted by Thresh, Beale and Suckling, 1949). The difference between the oxygen content of the light and dark bottles at the end of the experimental period is the oxygen production and the difference between the initial oxygen and that of the dark bottle is the oxygen consumption of the community. The oxygen production values are converted into its carbon equivalents using a PQ = 1·01 based on equivalents given by Laevastu (1958, Table 5).

Discussion of Results

The total annual production of carbon of the surface-waters of the first station from July 1957 to June 1958 was 88·792 gm./m^3, while from July 1958 to June 1959 it was 90·750 gm./m^3. The average annual production from all the analyses of the surface and depth samples from the six stations for the year 1959 was 88·730 gm./m^3. Calculated on the basis of these data the total annual production of carbon is 5,184,234 metric tons for an area of about 3,900 square kilometres of the sea with an average depth of 15 metres, extending from Dhanushkodi to Cape Comorin. It should, however, be mentioned here that although the six stations from

which data have been collected do not cover a major part of the southern region of the Gulf a broad assumption that the present figures are applicable for the entire zone has been made for computing the total production of this region.* During the corresponding period the total fish landing for this zone is 15,980 metric tons. Assuming that the average protein content of fish to be 20% of which 50% could be reckoned as carbon, *i.e.*, 10% of the wet weight of fish (Vinogradov, 1953), the fish landings represent 1,598 metric tons of carbon. So the annual yield in terms of carbon is only 0·03% of the total carbon production of the area which is exploited at present by the fishermen. Subrahmanyan (1958 and 1959) estimated the phytoplankton production for a potential fishing area of 1,55,400 square kilometres on the West Coast of India and believes that the landings of the West Coast represent only 1/10 to 1/30 of that in the English Channel.

It might be of interest to note that the production of the entire hydrosphere has been estimated by Steemann Nielsen and Jensen (1957) as 1·2 to $1·5 \times 10^{10}$ tons of carbon per year. According to them the annual yield of marine fishes as per the F.A.O. fishery statistics represents only 0·01% of the carbon annually fixed in the plankton algæ in all seas, whereas in eutrophic coastal areas at higher latitudes such as the North Sea, about 0·2 to 0·3% of the carbon annually fixed by the plankton algæ is taken every year by the fishermen. Steemann Nielsen and Jensen (1957) believe that a high precentage of yield is possible in eutrophic areas where plankton feeders abound. With only one link in the food chain, the percentage is bound to be high. According to this estimate it may be said that our present yield is only 1/7 to 1/10 of a possible exploitable stock, compared to the North Sea, on the assumption that the same percentage of carbon is being converted into exploitable fish stock.

Acknowledgement

The authors are grateful to Dr. S. Jones, Chief Research Officer, Central Marine Fisheries Research Station, for going through the manuscript and offering helpful criticisms. They are also thankful to the Fishery Survey Section of the Central Marine Fisheries for making available the survey

* Since this paper was sent to the Press, the authors were able to conduct one set of experiments off Tuticorin at the 8-fathom area in Kuthadi r P· ar, on September 6, 1960. It happened to be a period of *Rhizosolenia* bloom. Sampling was done just below the surface and at 5, 10 and 15 m. Production was highest near the surface (0·458 gm.C/m^3/day) which progressively diminished reaching compensation level at about 15 m. The production would thus amount to 3·435 gm.C/m^2/day. This value compares well with values obtained for the six stations during similar periods of diatom blooms.

data of the concerned zone and Sarvashri D. Sudarsana Reddy and C. T. Rajan for helpful co-operation in the collection and analysis of samples.

REFERENCES

Atkins, W. R. G. 1922 .. Hydrogen-ion concentration of sea-water in its biological relations. *J. Mar. biol. Assoc. U.K.*, **12**, 717–71.

———. 1923 .. Phosphate content of waters in relationship to growth of algal plankton. *Ibid.*, **13**, 119–50.

Clarke, G. L. 1946 .. Dynamics of production in a marine area. *Ecol. Monogr.*, **16**, 322–35.

Gaarder, T. and Gran, H. H. 1927 Investigations of the production of plankton in the Oslo Fjord. *Rapp. et Proc. Verb., Cons. Internat. Explor. Mer.*, **42**, 1–48.

Lævastu, T. 1958 .. *Review of the Methods Used in Plankton Research and Conversion Tables for Recording the Data and Recommendations for Standardization.* F.A.O. Fisheries Division, Biology Branch, FB/58/T2 (Mimeo.).

Prasad, R. R., Krishna Pillai, V. and Ramachandran Nair, P. V. 1958 A note on the organic production in the inshore waters of the Gulf of Mannar. *Curr. Sci.*, **27**, 302–03.

Riley, G. A. 1938 .. Plankton Studies.—I. A preliminary investigation of the plankton of the Totugas region. *J. Mar. Res.*, **1**, 335–52.

———. 1939 .. Plankton Studies—II. The Western North Atlantic, May–June, 1939. *Ibid.*, **2**, 145–62.

———. 1941 *a* .. Plankton Studies—III. Long Island Sound. *Bull. Bingham Oceanogr. Coll.*, **17**, 1–93.

———. 1941 *b* .. Plankton Studies—IV. Georges Bank. *Ibid.*, **7**, 1–73.

Steemann Nielsen, E. 1952 .. The use of radioactive carbon (^{14}C) for measuring organic production in the sea. *J. du. Cons.*, **18**, 117–40.

——— and Jensen, E. A. 1957 Primary Oceanic Production. The autotrophic production of organic matter in the oceans. *Galathea Reports*, **1**, 49–136.

Subrahmanyan, R. 1958 .. Ecological studies on the marine phytoplankton on the West Coast of India. *Mem. Indian Bot. Soc.*, **1**, 145–51.

———. 1959 .. Studies on the phytoplankton of the West Coast of India. Part I. Quantitative and qualitative fluctuation of the total phytoplankton crop, the zooplankton crop and their interrelationship, with remarks on the magnitude of the standing crop and production of matter and their relationship to fish landings. *Proc. Indian Acad. Sci.*, **50 B**, 113–87.

Thresh, J. C., Beale, J. F. and Suckling, E. V. 1949 *The Examination of Water and Water Supplies.* London, p. 280.

Vinogradov, A. P. 1953 .. *The Elementary Chemical Composition of Marine Organisms.* New Haven, pp. 647.

TRANSPORT OF THE COMMON CRAB (*SCYLLA SERRATA*) IN LIVING CONDITION

By R. B. Vasudeo and H. G. Kewalramani
(*Taraporewala Aquarium, Bombay*)

Storage and transport of live edible crustaceans, especially crabs and lobsters for marketing them at places distant from the fishing grounds, has been quite a recent development in the fishing industry. To perfect these methods of transport and to increase their longevity in captivity, investigations have been undertaken in several maritime countries.

In the U.S.A., England and France, floating stores, such as barges and pools have been devised, having adjustments for circulation, aeration and temperature control of sea-water, wherein lobsters and crabs have been kept alive for two to three months. Macleese and Wilder (1955) and Macleese (1956) first studied temperature, salinity and oxygen contents of sea-water under which lobsters live in natural conditions. Further studies on the acclimation of lobsters to these three factors enabled them to store lobsters alive under artificial conditions. Roach (1956) was able to store live crabs in large tanks on board the fishing vessel, with arrangements for continuous aeration, circulation and regulation of temperature of sea-water. In some cases, he preferred refrigerated sea-water in order to lower the oxygen consumption. Empey (1954) transported live lobsters in wooden barrels with ice and sea-weeds. He was able to keep the lobsters alive also in synthetic sea-water from six to sixteen days. In the year 1955, an all-metal float was introduced in the U.S.A. for ripening soft crabs.

In India, the consumption of live lobsters and crabs is more or less confined only to places near the fishing centres. However, if these could be transported to the places in the interior in as cheap and fresh condition as possible, there would be more demand for such crustacean delicacies than what it is existing at present. To find out a suitable method for their live transport, keeping the packing cost as low as possible, investigations were first undertaken on crabs.

Of all the commercial species of crabs, *Scylla serrata* (Forskål) is the most common and is caught in fairly large quantities all along the coast of India. Live specimens of this crab were obtained from local markets,

wherein they are brought with chelæ tied so as to facilitate their handling. When brought to the laboratory, the chelæ were let loose and the crabs were stored in the aquarium tanks wherein the sea-water was kept well aerated. They were conditioned to captivity for at least two days before taking them out for packing experiments. Prior to packing, the chelæ were tied again.

(A) Longevity of Crabs outside Sea-water

Five crabs were taken and were kept in thoroughly dried troughs, one in each trough. The troughs were covered with glass lids. Observations on their survival period (Table I) showed that crabs lived for 24 to 210 hours, depending upon the humidity percentage in the atmosphere.

Table I

Survival period of five crabs

Serial No. of the crab	Measurements		Sex	Survival period (hrs.)	Average temperature (° C.)	Average humidity (%)
	Length of carapace (mm.)	Breadth of carapace (mm.)				
1	42	63	Female	24	31·3	64·5
2	53	79	Male	48	31·1	66·0
3	40	60	„	196	27·3	90·0
4	55	82	„	210	26·0	91·1
5	44	57	„	175	28·0	86·3

(B) Packing of Crabs in Algæ

Fresh marine algæ, as packing material for retention of moisture in live crabs and lobsters, is commonly used in foreign countries. In Bombay, crabs and lobsters are brought alive to the markets in baskets with algæ and are generally disposed off the same day. This method, however, involves the risk of algæ itself being decomposed, specially in long transits as it sometimes happens when the containers are stacked one upon the other. To determine the harmful effects of algæ on the crabs in a closed container, the following experiment was conducted.

Two male crabs, with carapace length 47 and 44 mm., were enclosed separately in two tins with sea-weeds, so as to keep the gills of the crabs moist.

The sea-weeds used were washed with sea-water. The tins were opened after 24 hours. In both the tins the crabs were found dead. This led to the doubt whether crabs died because of the decomposition of sea-weeds or *vice versa*. Whatever was the cause, this showed that algæ as a packing material was not suitable.

(C) Packing of Crabs in Wet Cotton

The failure of algæ as packing material made it necessary to select some other material which would be less perishable. It was then considered that cotton soaked in sea-water, would serve the purpose. Two crabs, with carapace length 53 and 48 mm. respectively, were taken from the conditioning tank. These were put in layers of wet cotton and were kept for observation one in each glass trough covered with a glass lid.

Crabs under this condition were found to live as long as 17–18 days, with average atmospheric humidity of 83·5% and average atmospheric temperature of 27·9° C. As this experiment gave encouraging results, a further trial was made to study the condition of crabs in a small commercial packing. For this purpose, a wooden box, measuring $10'' \times 9'' \times 8''$, was taken, in which seven crabs were packed in wet cotton. This experiment was repeated twice and the box was opened after 24 and 72 hours, respectively. In both the cases, all the seven crabs were found alive and cotton had not dried up. Although packing of crabs in wet cotton was quite successful, it was later on realised that it would be a costly material if used for packing crabs on commercial scale. Besides, cotton after soaking with sea-water becomes compact and crabs do not seem to move as freely as they would in a loosely packed material. To comply these two requirements, it was considered that wood-shavings would form a suitable material.

(D) Packing of Crabs in Wood-shavings

Eighteen crabs with wood-shavings soaked in sea-water were packed in a wooden box measuring $18'' \times 12'' \times 6''$. The wood-shavings were not compactly packed and the lid of the box was nailed to it. After 48 hours, the box was opened and all the crabs were found alive. In order to facilitate the observation on their movement and mortality, the box with the same contents was repacked and covered with a glass sheet. The contents were checked every 24 hours and it was observed that the crabs moved freely

inside and came to the upper layers, but remained buried in the wood-shavings. The detailed observations are given in Table II which shows that the mortality of the crabs began after seven days.

TABLE II

Average temperature 26·1° C.
Average humidity 91·1%
Mortality:

Observations made after (in days)	Number of crabs dead
1	Nil
2	,,
3	,,
4	,,
5	,,
6	,,
7	,,
8	3
	5
10	4
11	6

It would not be unsafe, therefore, to send live crabs packed in soaked wood-shavings to any place comprising journey under seven days. As this method was found successful under the laboratory conditions, it became necessary to ascertain how far it would be applicable in the actual transport, involving elaborate journeys. A similar packing with eighteen crabs (Plate III) was despatched to Delhi by a passenger train. The consignment was opened at Delhi, 52 hours after it was packed in Bombay and all the crabs were found alive and healthy.

FIG. 1. A photograph showing crabs, packed in wet wood-shavings, ready for despatch.

Summary

1. *Scylla serrata* lived outside sea-water for the periods ranging from 24–210 hours, depending upon the humidity percentage in the atmosphere.

2. These crabs, when packed in a closed tin containing marine algæ, did not survive for more than 24 hours.

3. Algæ itself being a perishable commodity, cotton soaked in sea-water was used for packing and it was found that the crabs survived for 17–18 days.

4. For commercial packings, cotton being a costly material, crabs were packed in wood-shavings soaked in sea-water and it was found that crabs lived for seven days.

5. A trial consignment of 18 crabs packed in wet wood-shavings was despatched from Bombay to Delhi and all the crabs were found alive when the parcel was opened 52 hours after it was despatched.

The authors express their grateful thanks to Dr. C. V. Kulkarni, Director of Fisheries, Bombay, for granting the necessary facilities to work at the Taraporewala Marine Biological Research Station and for his helpful criticism in correcting the manuscript.

References

1. Empey, W. A. 1954 .. Fish landing and processing in U.S.A. lobsters. *Fisheries, News Letter*, **13** (6), 8.

2. Macleese, D. W. and Wilder, D. G. 1955 Suitable holding condition for live lobsters. *Progress Reports of* 1955 *of the Atlantic Coast Stations*, No. 62, pp. 24–28.

3. Macleese, D. W. 1956 .. Successful holding of live lobsters. *Canadian Fisherman*, **43** (3), 13–14.

4. Roach, S. W. 1956 .. Storage of live crabs in refrigerated sea-water. *Progress Reports of* 1956 *of the Pacific Coast Stations*, No. 106, pp. 6–7.

ON THE FISHING EXPERIMENTS CONDUCTED WITH A 10 FT. BEAM-TRAWL NET*

By S. D. Deshpande

[*Central Fisheries Technological Research Station (Craft and Gear Wing)*]

I. Introduction

Although the origin and history are not known, beam-trawl is an efficient fishing gear for bottom dwellers particularly shrimps. The net can be efficiently operated both from a sailing craft and a mechanised boat. This characteristic feature renders it as a possible "connecting link" between mechanised modern trawls on the one hand and similar towed gear from sailing crafts on the other. Beam-trawls and the like had been the initial step in many countries, where modern forms of trawl have come to stay. Scofield (1948) dates the origin of a similar fishing net on the Atlantic Coast over 500 years back and further indicates that the gear is still in vogue. In the countries like Thailand, Philippines and Japan, Beam-trawl still maintains its popularity for shrimp fishing.

Chidambaram (1952) states that exploratory fishing with a beam-trawl was conducted off Bombay in 1900. The results of these experiments are, however, not available. Kurian (1953) in his survey of the bottom fauna and bottom deposits of the Travancore Coast within the 15 fathom line used a 6′ beam-trawl "for collecting the bottom feeding fishes and other large organisms". Burroughs (1958) suggests the design of a beam-trawl suitable for operation in Indian waters from low-powered vessels. Apart from these references, concentrated efforts to introduce this fishing gear in India do not appear to have been made so far. The present author is of opinion that, since mechanisation of small fishing crafts is fast progressing in most of the maritime states, beam-trawls, if introduced, would be particularly useful in stabilising the base of the future trawl fishing in this country. Details of the first series of experiments conducted with a 10′ beam-trawl net from a small motorized craft are presented in this communication.

II. Place of Experiment and Fishing Ground

The experiment was conducted in the sea off Cochin, where shrimps contribute to a fishery of economic importance and both indigenous and to a

* Contribution No. 13.

certain extent modern gear are in use for their exploitation. ' Thangu vala ' (Malayalam), a single-boat seine, is a popular gear for the capture of shrimps, while otter-trawls are being operated by the mechanised fishing vessels of the Government agencies. To facilitate comparison of the catches, experimental fishing with the beam-trawl was done in close association with a few of the mechanised boats and a country craft.

The fishing area was within 9° 38′ to 9° 55′ N. Latitude and 76° 9′ to 76° 16′ E. Longitude (Text-Fig. 1).† The mechanised vessels ' Durga ' and ' Tarpon ' of the Government of India Off-Shore Fishing Station, ' Mermaid ' of the State Fisheries Department and a country canoe from the coastal fishing village of Moolankuzhi were operating in the same area during the period of these experiments.

The depth of the fishing ground ranged from $4\frac{1}{2}$ to 13 fathoms. The bottom was muddy (soft mud) for most part interrupted by a conical area of shell ooze admixed with mud (Text-Fig. 1).

III. Period of Operation and Procedure

The operations commenced from 6-5-1959 and continued up to 16-5-1959. During the period of 10 days, eight fishing trips were undertaken and 39 hauls, covering a total duration of 30 hours and 55 minutes, were made. The onset of the monsoon curtailed the possibility of further operations.

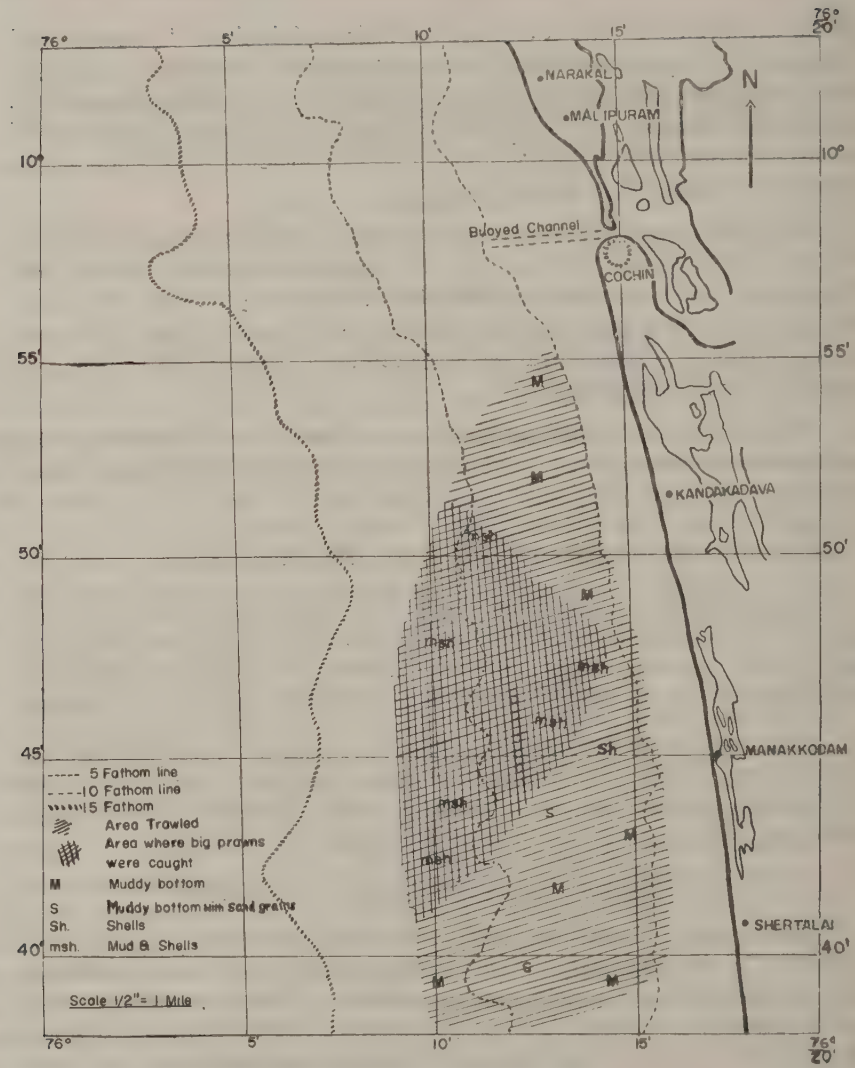
Field data about the design of the nets, depth of water, length of warp for each drag, duration of the drag and speed of the vessel while towing were recorded for local as well as mechanised crafts. Particulars of the fishing operations and the catches with these vessels were also recorded.

IV. Design of the Net Used for Experiment

Design and constructional details of the 10′ beam-trawl are shown in Text-Fig. 2. The webbed portions, using the reef-knot, were fabricated with the aid of a hand-driven net-making machine. Russian cotton twines of specifications 32/6/3 (Count No. 32 ; 3 strands ; 18 threads) were chosen as the material for the webbing. The size of the stretched mesh was 1″ (25 mm.) throughout.

The coir ' Head rope ' was 0·5″ (12·5 mm.) diameter, 19′ (5·79 M) long and carried 10 oblong thermocole floats each having a buoyancy of 0·56 lb. (0·25 kg.). The ' Foot rope ' also of coir, was 27′ (8·226 M) long and

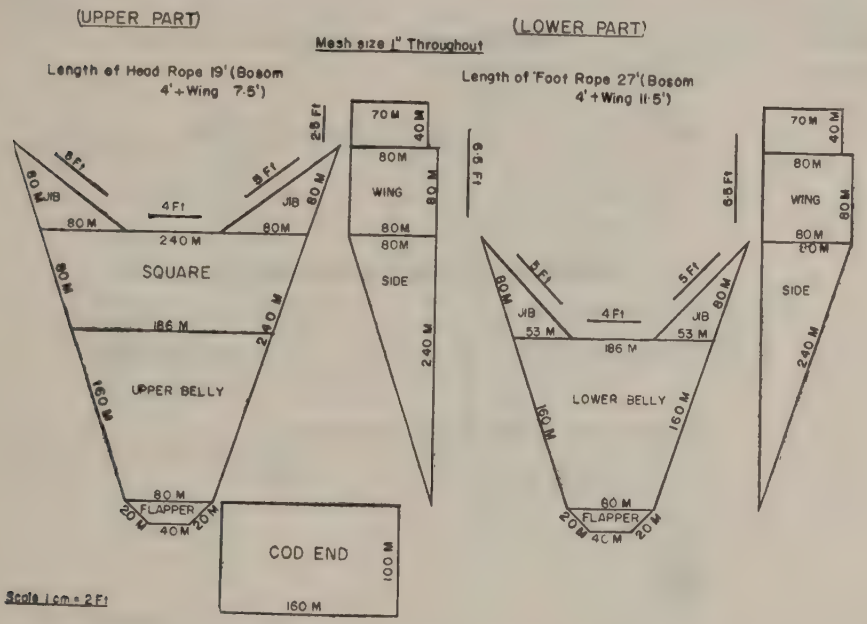
† Based on *Admiralty Charts No.* 749 and 750.



TEXT-FIG. 1. Chart showing fishing grounds off Cochin.

0·75" (18·75 mm.) diameter. Thirty lead sinkers, each weighing 0·45 lb. (0·204 kg.), were attached to this rope. The overhang of the 'head rope' in advance of the 'foot rope' was a little less than 6' (1·9 M).

The 'Beam' (Text-Fig. 3 B) was 10' (3·46 M) long and the height of the 'Beam leg' (Text-Fig. 3 C) at either ends being 2' (0·609 M). The method



TEXT-FIG. 2. Diagram showing constructional details of a 10′ beam-trawl used for experiment.

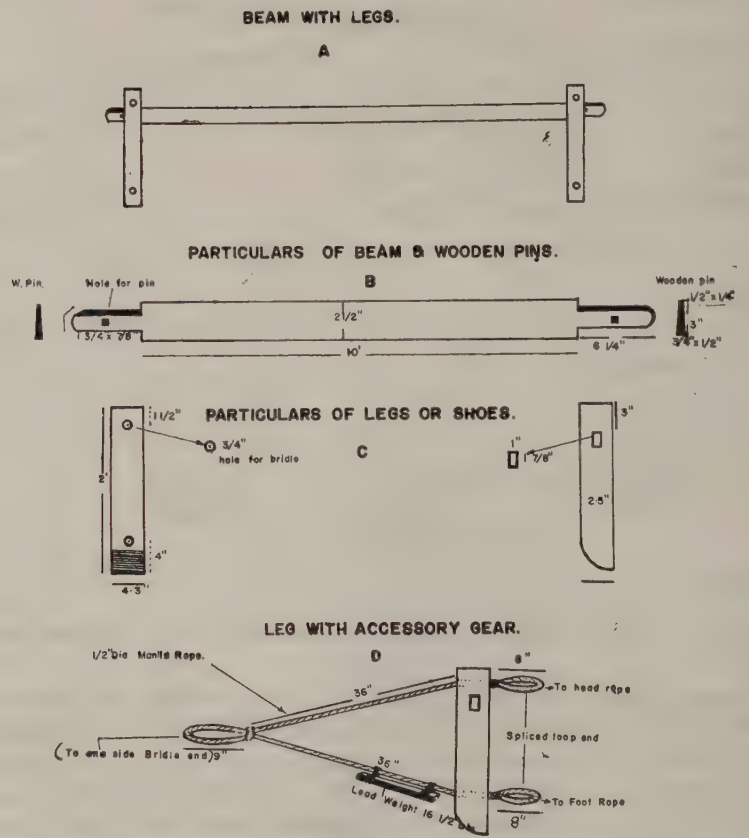
of fastening ' head ' and ' foot ' ropes to the ' short bridles ' are illustrated in Text-Fig. 3 D. To the lower legs of the ' short bridles ' lead weights weighing 16·5 lb. (7·47 kg.) were attached to compensate the loss of weight caused by the absence of ' trawl-heads ' or ' shoes ' usually present in the conventional types of ' beam-trawl '. The ' bridles ' proper were sisal ropes of diameter 0·75" (18·75 mm.) and length of each ' bridle-leg ' being 8 fathoms. The single ' warp ' (or ' tow line ') was shackled to the union where the ' bridles ' of either side were joined together. To this shackle, a cement weight of 67 lb. (29·8 kg.) was also attached. Text-Figure 4 illustrates the general arrangement.

V. SPECIFICATIONS OF THE BOAT USED FOR EXPERIMENT

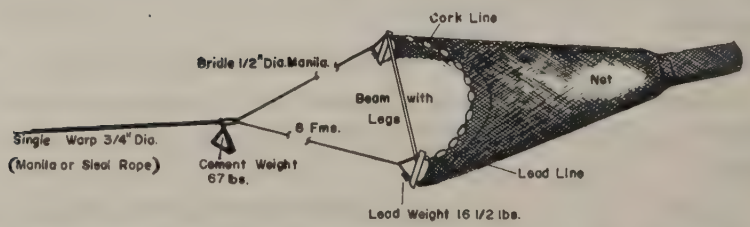
The Research vessel ' Fishtech I ' attached to the station was used for the experiments. The specifications of the boat are as follows:

(*i*) *General*

Type	..	' Pablo ' type with transom stern
Design	..	Based on the ' lines plan ' of Mr. Paul B. Zeiner, F.A.O. Naval Architect



TEXT-FIG. 3. Showing details of accessory gear.



TEXT-FIG. 4. Diagram showing 10′ beam-trawl with bridles, weight and single warp.

Year of Construction	..	1958 (Constructed at the Central Fisheries Technological Research Station, Cochin)

(*ii*) *Dimensions*

Length overall	..	30′ 0″ (9·14 M)
Length C.W.L.	..	28′ 0″ (8·53 M)
Breadth (Max.)	..	8′ 2″ (2·48 M)
Depth (Moulded)	..	4′ 1″ (1·244 M)
Draught (C.W.L.)	..	2′ 10″ (0·863 M)
Displacement to C.W.L.	..	4·6 tons

(*iii*) *Particulars of Engine*

Type	..	Marine Semi-Diesel
Make	..	' Seffle ' Sweden.
B.H.P.	..	30

(*iv*) *Particulars of Crew*

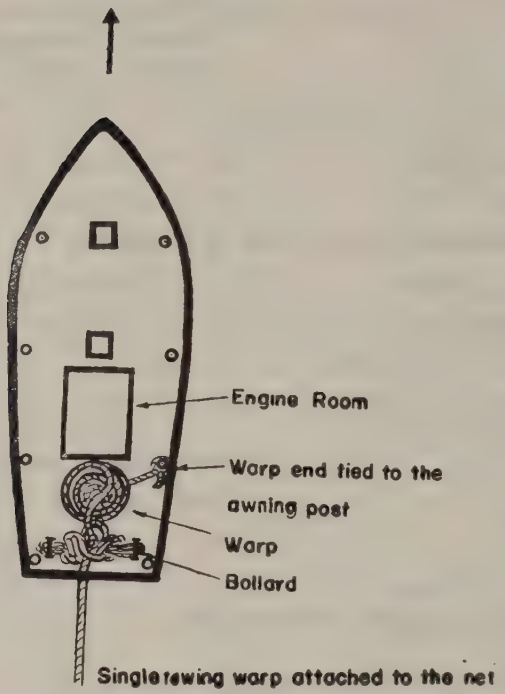
Tindal *cum* Driver	..	1
Lascars	..	3

Since the vessel is not provided with a mechanical fishing winch, the operations (shooting and hauling) of the net were done by hand.

VI. Method of Operation

(*a*) *Deck arrangement.*—Certain arrangements had to be made to facilitate towing of the net. Two bollards were fixed, one on either side of the stern-deck, and a coir rope (0·75″ to 18·7 mm. diameter) was tied round these to form 4 strands across the stern. To this, the warp end was secured as shown in Text-Fig. 5.

(*b*) *Shooting of the net.*—After taking the necessary soundings (for depth and nature of bottom) of the fishing ground, the boat was steered at slow speed in the direction of the trawling course and the net paid out in the order of cod-end, body, beam, bridle, cement weight and warp. The warp carried distinct marks at intervals of 10 fathoms to facilitate determination of the exact length of tow-line used for the drag. The trawling speed ranged between $1\frac{1}{2}$ to 3 knots depending on the length of the warp.



TEXT-FIG. 5. Showing deck arrangement on board 'Fishtech 1'.

(*c*) *Duration of Drag.*—After an initial trial haul each day, four to five regular fishing hauls were made. The duration of each fishing haul was between 45 to 60 minutes.

(*d*) *Hauling-in the net.*—On completing the drag, heaving-in the warp by hand was undertaken. To minimise the strain, the engine was made to go astern till about 10 fathoms of the warp remained. The engine was then put to neutral position and remaining warp and the cement weight were hauled on board. The ends of the main-bridles, towards the cement weight, were secured to bollard of the respective side and the vessel steered ahead at normal speed. This helped to lift the beam with the net to the water surface. The vessel was then manoeuvred in such a way that the direction of the wind was abaft. The engine was put to neutral position and the bridles were heaved in. The beam was hoisted and hauling-in of actual net commenced. The net was then lifted and fish removed from the cod-end. When the catch was heavy, the cod-end portion of the net was brought forward to port side of the vessel

and a 0·5″ (12·5 mm.) diameter, 2 to 3 fathoms long manila rope, having two lead sinkers in the centre, called the ' splitting strap ' was passed around the cod-end portion to split up the load of the fish. The split up portion of fish towards the cod end was then hoisted and strapped aboard. The emptied cod-end was secured with the string and returned to water so that another portion of the catch could be pinched off and hoisted. After final stripping, the cod-end string was secured and the net left in water. The boat was then steered ahead with the net behind for second lay out. The beam, bridles, cement weight and the towing warp followed.

VII. Results of Experiment

Results of the fishing experiments are tabulated in Table I.

Table I

Showing details of fishing trips made by ' Fishtech I '

Sl. No.	Date	Soundings in fathoms	Length of warp used in fms.	Towing speed (Knots)	Number of hauls	Total duration of hauls in minutes	Catch in lb.		Average catch per hour	
							Prawns	Fish	Prawns	Fish
1	6-5-1959	4 - 7	40-45	1½-2	3	90	153	10	102	6·6
2	8-5-1959	4½- 7½	40-46	1½-3	6	290	65	21	13·4	4·3
3	9-5-1959	5 - 7½	40-45	2½	4	165	..	14·5	..	5·2
4	11-5-1959	5¼- 7½	40-55	2½-3	7	300	264	131	52·8	26·2
5	12-5-1959	7	50	2½-3	6	330	502	218	91·2	39·6
6	13-5-1959	6 - 8½	45-60	2½	4	185	105	95	34·05	30·8
7	14-5-1959	7 - 9½	50-90	2½-3	5	285	57·5	62	12·1	8·05
8	16-5-1959	9 -12½	60-70	2	4	210	35	95	10	27·1
	Total ..	..	..	..	39	30 hr. & 55 min.	1,181·5	646·5	38·23	20·90

It would be evident from Table I that the catch per hour on the ground operated works out to about 38·23 lb. (17·342 kg.) of prawns and 20·90 lb. (9·489 kg.) of fish.

VIII. Discussion

(*i*) *Volume of water filtered.*—The volume of water filtered per hour by beam and otter-trawls as shown in Table II was worked out by taking into

consideration the vertical as well as the horizontal opening of the net while in operation.

TABLE II

Showing general details of different vessels

Procedure followed for calculating the opening of the net and the volume of water filtered by nets is described in the appropriate paras of the text

Sl. No.	Name of vessel	Size of boat (overhual length in feet)	H.P. of engine	No. of crew on board	Type of gear used	Size of the net used		Average towing speed (knots)	Opening of net while fishing in feet		Volume of water filtered per hour in cubic feet
						Head rope (ft.)	Foot rope (ft.)		Horizontal	Vertical	
1	Local dug-out canoe	42	..	11	Thangu Vala, a local seine operated from one boat	168	168	..	..	..	.
2	Fishtech I	30	30	4	Beam-trawl	19	29	2½	10	2	3,04,000
3	Mermaid ..	31-9″	30	5	Otter-trawl	54	62	2½	37·8	4	22,95,000
4	Tarpon ..	36	42	5	do.	52	53	2½	36·4	4·5	24,92,800
5	Durga ..	36	56	6	do.	60	60·5	2½	42·5	5	31,92,000

The horizontal opening of the beam-trawl is the length of the beam and the vertical opening the height of the beam legs. The approximate horizontal and vertical opening of different otter-trawls was assessed from the length of the ' Head rope ' or size of the net. The horizontal opening of the net was assumed to be about 70% of the length of the head rope, presuming that the net was in its best fishing condition.‡

After calculating the horizontal and vertical opening of the net and the speed of the vessel per hour while trawling, the volume of water filtered by each net was worked out from the following formula:

$$V = B \times H \times S.$$

Where ' V ' denotes the volume of water filtered, ' B ', ' H ' the horizontal and vertical openings respectively and ' S ' the distance for which the net was towed during one hour.

‡ Based on a personal communication from Dr. H. Miyamoto.

(*ii*) *Comparison of catches.*—It would be evident from Table III that the catch per hour of shrimps in respect of local craft, ' Fishtech I ', ' Mermaid ', ' Tarpon ' and 'Durga ' was in the order of about 39·75 lb., 38·23 lb., 12·42 lb., 437·32 lb. and 208·16 lb., whereas the catch per head per day calculated from the number of crew engaged while fishing worked out to about 12·34 lb., 36·93 lb., 12·40 lb., 301·33 lb. and 167·68 lb. respectively.

TABLE III

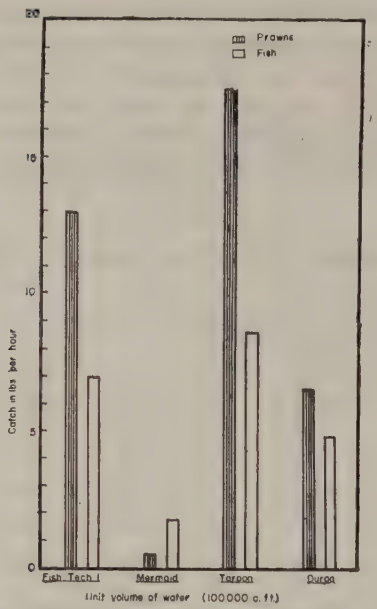
Showing the quantities in lb. of fish landed by different vessels

Sl. No.	Name of vessel	No. of days finished from 6 to 16-5-59	Depth of water in fms.	Total No. of hauls	Total duration of hauls		Catch in lb.		Catch in lb. per hour		Catch per head per day in lb.	
					Hrs.	Min.	Prawns	Fish	Prawns	Fish	Prawns	Fish
1	Local dugout canoe	6	2 – 5½	68	20	30	815	695	39·75	33·9	12·34	10·53
2	Fishtech I..	8	4½–13	39	30	55	1,181·5	646·5	38·23	20·92	36·93	20·21
3	Mermaid ..	5	7 –12	26	24	55	310	1,080	12·42	43·32	12·40	43·20
4	Tarpon ..	9	6 –13	31	31	..	13,560	6,645	437·32	214·35	301·33	147·67
5	Durga ..	8	6 –13	31	38	40	8,049	6,046	208·16	156·43	167·68	125·95

Comparing the catch efficiency of beam-trawl and local seine nets, it is evident that catch per head per day in the case of beam-trawl is three times the catch of the local gear. Mr. Illugason, F.A.O. Fishing Expert, appears to have proved the superiority of flat trawl over the local seine gear operated in areas from Cannanore to Kadalur for capture of shrimps (John *et. al.*, 1959).

The volume of water filtered by different trawl nets per hour, indicated in Table II, is related to the size of the net. Since, the beam-trawl used for experiment was very small having an opening of $10' \times 2'$ the volume of water filtered per hour was less when compared with the volume of water filtered by other trawls. Assuming 10^5 (one lakh) c. ft. of water filtered as a unit for all the nets, the catch per unit volume of water filtered per hour calculated in respect of different vessels determines the catch efficiency of each net. The catch per 10^5 c.ft. of filtered water in respect of mechanised boats is shown in Text-Fig. 6.

It would be evident from the histogram that the catch of prawns landed by ' Fishtech I ' stands second to the catch brought by the mechanised fishing



TEXT-FIG. 6. Showing amount of catch of fish and prawns in lb. per hour. The unit of water filtered remaining constant.

vessel 'Tarpon'. Therefore, there is very little difference in the catching power of beam and otter-trawl nets on the basis of the volume of water filtered through each.

(*iv*) *Prospects for popularising this method.*—The beam-trawl net could be used successfully on small low powered fishing crafts and unlike an otter-trawl can be operated in waters as deep as 100 fathoms (Burroughs, 1958). According to Domantay (1955) and Miyamoto (1956), the beam-trawl could be conveniently operated from a sailing vessel as similar type of fishing is in vogue in East Asian countries like Philippines and Japan. Fishing with 3 to 5 beam-trawls operated from a single boat having 2 to 3 sails is a characteristic feature of the Japanese fishing industry (Onda, 1951). Beam-trawl fishing in inshore waters of British Islands is being practised by small inshore fishing crafts and beam-trawls are also used to a certain extent in the West European and Mediterranian Coastal waters from medium size motorized vessels (Morgan, 1956).

Good results can be obtained from this net in brackish water lakes and freshwater reservoirs, where the bottom is free from rocks and other obstructions, so far as capture of bottom fishes are concerned.

Trial fishing with this net in areas where there is a strong tidal current will be quite interesting since a set of 5 to 10 nets could be conveniently anchored as a 'Stream net'.‡ In case of non-availability of fish in inshore areas during a particular period, same can be shifted to any depth which in turn would be helpful in exploring new grounds or in knowing the migratory habits of fishes in deeper waters.

The operational technicalities are minimum in the case of beam-trawl and from personal experience, the author is of the opinion that any number of fishermen could be trained within a short time in the operation of this gear.

IX. Acknowledgements

The author wishes to express his gratitude to Dr. H. Miyamoto, F.A.O. Gear Technologist, for designing the 10′ beam-trawl net and offering very valuable suggestions during the course of experiment. The author is also indebted to Shri G. K. Kuriyan, Assistant. Director (Gear), Central Fisheries Technological Research Station, Cochin, for going through the manuscript and making useful suggestions for its improvement. Thanks are also due to the Bosuns of the mechanised fishing vessels 'Tarpon' and 'Durga' for facilities afforded to take necessary measurements and fishing data. To Shri V. T. George, Superintendent and Shri T. J. Mathew, Technical Assistant of the Fishermen Training Centre, Ernakulam, the author is grateful for furnishing the catch statistics of the vessel 'Mermaid'.

X. Summary

The paper deals with the design, construction and operational details of a 10′ beam-trawl in the sea off Cochin.

The comparative account of the catch efficiency of a local boat-seine, beam-trawl and otter-trawl has been given along with the particulars of procedure followed in calculating the volume of water filtered per hour by beam- and otter-trawl nets.

Advantages of a beam-trawl over the indigenous gear have been discussed.

A comparison of catch data shows very little difference between the catch landed by beam and otter trawls when the volume of water filtered by each net per hour was considered as unit.

‡ Based on lectures delivered by Mr. P. A. Lusyne, F.A.O. Gear Technologist, on the classification of fishing gear.

XI. References

Burroughs, J. L. 1958 .. Beam-trawls for small mechanised fishing crafts. *Paper Submitted at the Symposium on "Improved Types of Fishing from Small Mechanised Boats," held at Cochin during October* 1958.

Chidambaram, K. 1952 .. The experimental introduction of powered fishing vessels within India and Ceylon. *Occasional Paper, IPFC.*

Domantay, J. S. 1955 .. Prawn fisheries of Philippines. *Ibid.*

John. V., Chacko, P. I., Venkatraman, R. and Shariff, A. T. 1959 *Report on the Fishing Experiments in the Off-Sea Waters of the Madras State*, Government Press, Madras.

Kurian, C. V. 1953 .. A preliminary survey of the bottom fauna and bottom deposits of the Travancore Coast within the 15 fathoms line. *Proc. Nat. Inst. Sci. India*, **19** (6), 741–771.

Miyamoto, H. 1956 .. *Theory of Fishing Gear and Method* (Japanese). Kanehara Press Ltd., Tokyo.

Morgan, R. 1956 .. *World Sea Fisheries.* Methuen & Co., Ltd., London.

Onda, Y. 1951 .. Sailing trawl fisheries in Seto Inland Sea (Japanese). *Fisheries of the Seto Inland Sea*, **5**.

Scofield, W. L. 1948 .. Trawling gear in California. Division of Fish & Game, *Fish Bull.*, No. 72, 1–60.

GOVERNMENT OF INDIA
CENTRAL MARINE FISHERIES RESEARCH STATION, MARINE FISHERIES P.O., MANDAPAM CAMP, SOUTH INDIA

ANNUAL REPORT OF THE CHIEF RESEARCH OFFICER FOR THE YEAR ENDING 31st MARCH 1959

CONTENTS

		Page
I.	Administrative and General	188
II.	Fishery Survey	194
III.	Fishery Biology—	
	A. *Inshore Fisheries Investigations*:	
	(1) Oil-sardine—*Sardinella longiceps* and other clupeoids	199
	(2) Mackerel—*Rastrelliger canagurta*	204
	(3) Prawns	206
	(4) Half-beaks—*Hemirhamphus* spp.	210
	(5) Seer-fish—*Scomberomorus guttatus*	210
	(6) Mullets—*Mugil* spp.	211
	(7) Tunny—*Katsuwonus pelamis*	211
	(8) Spiny Lobsters—*Panulirus* spp.	212
	(9) Molluscs	213
	B. *Offshore Fisheries Investigations*:	
	(*a*) Mechanised Fishing at Bombay:	
	(1) Biology and Fishery of Dara (*Polydactylus indicus*)	214
	(2) Biology and Fishery of Shende (*Polynemus heptadactylus*)	215
	(3) Biology and Fishery of Ghol (*Pseudosciæna diacanthus*)	215
	(4) Biology and Fishery of Koth (*Sciænoides brunneus*)	215
	(5) Biology and Fishery of Karkara (*Pomadasys hasta*)	216
	(6) Biology and Fishery of Bombil (*Harpodon nehereus*)	216
	(*b*) Mechanised Fishing at Cochin	217
	(*c*) Mechanised Fishing at Calcutta	218
	C. *Physiology and Marine Fish Farming*	221
IV.	Marine Biology	
	A. *Planktological Investigations*	222
	B. *Oceanographic Studies*	225
	C. *Algology*	228
V.	Chemistry and Bacteriology of Fish; Fish Curing and By-Products	229
VI.	List of Publications during the Year	230

I. Administrative and General

Steady progress was maintained during the year 1958–59 in the implementation of the programmes of work both under the Normal and Second Five-Year Plan Schemes at the Headquarters Station and the various subordinate establishments. The construction of the permanent substation building at Calicut at a cost of over Rs. 2 lakhs was completed and it was formally inaugurated by the Deputy Minister for Agriculture, Shri M. V. Krishnappa, on the 1st October 1958. Prof. Joseph Mundassery, Minister for Education and Fisheries, Kerala Government, presided over the function and opened the Fisheries Exhibition conducted there. The Souvenir entitled *The Fisheries of the West Coast of India* issued to mark the occasion was well received by fishery workers both in India and abroad and the Exhibition proved to be a great success. Active efforts made for the collection of scientific data and material from the Minicoy-Laccadive area yielded very interesting results. For study of offshore fisheries the staff posted at Ernakulam was strengthened and new centres were opened at Tuticorin and Veraval. The Research Centres at Kandla and Tuticorin have been raised to the status of Research Units. New Survey/Field Centres were opened at Alibagh, Dahanu, Calingapatna and Colachel.

An aggregate budget allotment of Rs. 14·7 lakhs under the Normal and Second Five-Year Plan Schemes was sanctioned for the year. On the capital works side the completion of the Calicut Substation building as also the permanent staff quarters at Mandapam and the occupation during the year deserve special mention. Construction of the Guest House at Mandapam also made substantial progress. An additional overhead tank for circulating sea-water-supply to the Aquarium was also completed and put into commission.

With enhanced financial powers delegated by Government it has been possible to effect timely procurement and supply of essential scientific equipment required for the different sections. Scarcity of certain imported items of scientific equipments proved to be a handicap. But with the foreign exchange sanction, recently accorded by Government, it is hoped to procure from abroad some of these items during 1959–60. For experimental fishing and collection of data a 7½ H.P. westbend outboard motor was purchased. The Pablo Boat from Ernakulam has been transferred to the Headquarters Station. A 75/100 B.H.P. motor boat for use for fisheries reaserch work on the west coast has been received at Ernakulam. The Dan Boat at the Headquarters Station has been temporarily transferred for use at the Tuticorin

Research Unit. A lathe ordered during the previous year has been received and installed in the workshop. The jeep temporarily transferred to the Ernakulam Substation has again been brought back to Headquarters Station.

Substantial increase in the accessions to the Library took place besides continuing existing subscriptions to existing periodicals. Library facilities at the subordinate establishments were also augmented by regular circulation of selected number of journals as also by the loan publications and by the transfer of duplicate copies from the Headquarters Library.

Vol. V, No. 2 of the *Indian Journal of Fisheries* was published and Vol. VI, No. 1 is in press. Over 130 copies of each issue of the Journal are mailed free to various institutions interested in fisheries work and in addition about 50 copies are sent out in exchange for publication received in the Library of the Research Station. Demand for copies of the *Indian Journal of Fisheries* on regular subscription basis is also steadily on the increase. Copies of the Souvenir *The Fisheries of the West Coast of India* were also distributed to various departments and organisations. Certain number of publications were sent on permanent transfer to the Central Fisheries Technological Research Station. Facilities of the Library were also made available to visiting workers and specialists working at other institutions.

For the implementation of the programme of work under the Second Five-Year Plan, the following posts were created during the year:

Assistant Research Officers (Pelagic Fisheries) ..	2 posts
Assistant Research Officers (Mackerel), (Sardine) and (Offshore Fisheries)	3 „
Research Assistants	3 „
Field Investigators	4 „
Senior Caretaker	1 post
Motor Boat Driver-*cum*-Serang	1 „
Field Assistants	4 posts
Lower Division Clerks	2 „

The following appointments and promotions had taken place during the year:

Name of Officer	*New Post*	*Previous post held*
Dr. G. Seshappa	.. Research Officer (Fishery Biology)	Assistant Research Officer (Marine Zoology)
Shri K. H. Mohamed	.. Research Officer (Offshore Fisheries)	Research Officer (Sardine)
Dr. V. Balakrishnan	.. Assistant Research Officer (Offshore Fisheries)	..
Shri M. Rajendranathan Nair	.. Assistant Research Officer (Fish Curing)	Research Assistant
Shri V. Balan	.. Assistant Research Officer (Sardines)	Do.
Shri S. Ramamurthy	.. Assistant Research Officer (Prawns)	Research Assistant
Dr. P. Vijayaraghavan	.. Assistant Research Officer (Mackerel)	Do.
Shri N. Radhakrishnan	.. Assistant Research Officer (Sardines)	Do.
Shri K. Venkatanarayana Rao	.. Assistant Research Officer (Mackerel)	Do.
Shri M. S. Muthu	.. Assistant Research Officer (Offshore Fisheries)	Do.
Shri B. T. Antonyraja	.. Assistant Research Officer (Pelagic Fisheries)	Do.
Shri M. Mydeen Kunju	.. Assistant Research Officer (Prawns)	Assistant Research Officer at CIFRS
Dr. M. D. K. Kuthalingam	Assistant Research Officer (Offshore Fisheries)	..

Dr. N. K. Panikkar, who held the post of Chief Research Officer of this Station in a permanent capacity, was confirmed in the post of Fisheries

Development Adviser at the Ministry of Food and Agriculture, New Delhi, with effect from 26–4–1957. Dr. H. L. Arora who was holding the post of Research Officer (Fishery Survey) (Class I, Junior) was relieved from the post at his own request. Dr. A. Anantharama Sastry and Shri A. S. R. Sarma who were holding the posts of Assistant Research Officers (Physical Oceanography) and (Statistics) respectively were also relieved from this Department to take up appointment in higher posts elsewhere.

The formation of the Processing Wing of the Central Fisheries Technological Research Station at Ernakulam took place in December 1958 by the transfer of the following staff members along with the posts held by them:

1. Dr. V. Krishna Pillai, Assistant Research Officer (Bacteriology).
2. Shri P. V. Kamasastry, Assistant Research Officer (By-products Utilization).
3. Shri M. Rajendranathan Nair, Assistant Research Officer (Fish Curing).
4. Shri T. K. Govindan, Research Assistant.
5. Shri A. P. Valsan, Extension Assistant.
6. Shri M. Abdul Sathar, Laboratory Attender.

Sarvashri M. J. George, B. Krishnamurthy, K. V. Sekharan, K. Nagappan Nair and T. Tholasilingam were confirmed as Research Assistants while Shri V. Balan and Shri V. Somanathan were confirmed as Survey Assistant and Typist Clerk respectively. Sarvashri S. V. Suryanarayana Rao, S. Ramamurthy, V. Krishna Pillai, N. Radhakrishnan, P. V. Kamasastry, C. Mukundan, M. Rajendranathan Nair, Miss P. D. Nayak and R. Prasanna Varma were declared quasi-permanent in the post of Research Assistants; while Miss H. Kamala, Shri M. P. Laskhmanan and Shri S. PL. Sethu were made quasi-permanent in the posts of Librarian, Typist Clerk and Despatch and File Clerk respectively.

A second post of Superintendent was filled by the promotion of Shri S. Rajagopalan, permanent incumbent of the post of Accountant. Recruitment to a number of vacant Class III posts was made during the year. Confirmation of certain members of Class IV staff in vacant permanent posts and quasi-permanent appointment of others eligible for the same also took place during the year.

The Chief Research Officer participated in the meeting held at Bombay on 13–6–1958 for co-ordination of fisheries research there; the Fishery

Research Committe meeting held at Srinagar in July 1958, and the Indian Science Congress Session held at New Delhi in January 1959.

Shri K. H. Mohamed, Research Officer, completed a course of 6 months' training in Japan, Shri M. S. Prabhu, Assistant Research Officer, returned to India in November 1958 after completion of a 6 months' training in Canada in bottom fisheries. Shri N. K. Velankar, Research Officer, who went to Canada for advanced training, had to return to India owing to ill-health before the completion of the training. Dr. P. Vijayaraghavan and Shri K. Venkatanarayana Rao, Research Assistants, participated as trainees in the F.A.O. International Training Centre for methodology and techniques of research on mackerel held at Bangkok in October–December 1958. A similar refresher course in Marine Biology held at Bombay was attended by Shri C. Mukundan, Research Assistant. Sarvashri P. C. George, Assistant Research Officer and K. Krishna Rao, Research Assistant, were deputed to attend as trainees in the Indo-Pacific Training Centre in Fisheries Statistics conducted at Bombay under the auspices of the F.A.O. Shri S. K. Banerji, Research Officer, also took part in this course as a Lecturer. Dr. R. Viswanathan, Assistant Research Officer (Oceanography), who was in Germany on study leave, was awarded *Dr. rer nat.* degree of the Kiel University. He returned to India in December 1958 to take charge of his post. Sarvashri K. Nagappan Nair, M. S. Prabhu and B. T. Antonyraja, Assistant Research Officers were given training in the use of aqua-lung at Tuticorin under Dr. Baschieri Salvadori, F.A.O. Expert for Underwater Exploration.

Regular classes were conducted for teaching Hindi to the gazetted and non-gazetted staff. Sixteen members of the staff appeared for the Prabodh examination conducted by the Ajmir Board of Secondary Education of whom more than 50% came out successful.

Dr. F. Morawa, who worked at this Institute as a Research Fellow under the Indo-German Industrial Co-operation Scheme, completed his work and left India in October 1958. Dr. Karl Banse, the second German Research Fellow, is continuing his investigations here.

Sarvashri K. K. Tandon and M. Subrahmaniam, Senior Research Scholars, actively pursued their studies at this Institute. Sarvashri P. S. B. R. James, A. N. P. Ummer Kutty and C. Sankaran Kutty have joined as Senior Research Scholars during the year. Sarvashri S. Malhotra and K. Krishnamurthy, who were working earlier as Research Scholars, have been relieved from their assignments as requested by them. Shri P. K. Eappen, who was an Honorary Research Worker, was appointed as Assistant Director in the

Deep-Sea Fishing Station, Bombay. Shri K. Ramalingam was awarded the Ph.D. of the Madras University on the basis of the thesis submitted by him embodying the results of the research work carried out at this Institute as Senior Research Scholar.

Shri Bishnuram Medhi, Governor of Madras and Mrs. Medhi, visited the Research Station on 25–2–1959. The distinguished visitors were taken round by the Chief Research Officer and the work in the different sections were explained to them. The Fishery Education Committee of the Government of India with Dr. N. K. Panikkar as Chairman and Dr. B. N. Chopra and Prof. G. M. Gerhardson as members visited the Research Station on 4–2–1959. Among other distinguished visitors could be mentioned Shrimati Lourdammal Simon, Minister for Local Administration and Fisheries, Madras Government, who visited this Research Station on 3rd and 4th January 1959 in connection with the Madras Fisheries Advisory Board meeting and the State Fisheries Officers Conference when Shri P. P. I. Vaidiyanatham, I.C.S., Secretary, Food and Agriculture, Department of the Madras Government, Shri C. P. Kelu Erady, I.A.S., Director of Fisheries, Madras and a large number of Officers of the Madras Fisheries Department and other delegates were present. Other notable visitors were Prof. N. G. Ranga, M.P., Chairman of the Public Accounts Committee and Mrs. Bharati Devi Ranga, M.L.C., Dr. Bachieri Salvadori and Mrs. Salvadori, Mr. J. A. Gulland of the Lowestoft Fisheries Laboratory, England, Mr. R. O. Smith, T.C.M. Fish Marketing Expert, Mr. Peter Gurtner, F.A.O. Naval Architect, Mr. M. R. Khan, Assistant Regional Officer of the F.A.O., Bangkok, Messrs. T. Lashin and Abdel Khalek El-Sayed Imam of Egypt, Shri L. R. S. Singh, Chief Commissioner of Pondicherry Administration, Dr. N. K. Gupta of the Punjab University, Shrimati Grace Tucker, Deputy Minister for Education, Mysore State and Shri G. M. Muthusamy Pillai, Collector of Ramanathapuram at Maduari. Shri E. M. Sankaran Namboodiripad, Chief Minister of Kerala and Shri A. M. Thomas, Union Deputy Minister for Food visited the Kozhikode Substation.

There has been an increase in the numbers of different categories of visitors to the Research Station. Numerous enquiries received from diverse sources have been answered when information and details requested for by various departments, organizations and parties were supplied. The research programme, carried out in collaboration with the Indo-Norwegian Project authorities in Kerala, made steady progress and a number of cruises were carried out by the research staff of this Station on board their research vessel "Kalava" in different areas of the Arabian Sea. The scheme on the

collection and analysis of sea-water samples and other data and their study sanctioned by the Ministry of Scientific Research and Cultural Affairs was effectively continued. Cotton and nylon twines required for collaborated work with the Gear Wing of the Central Fisheries Technological Research Station at Cochin were also indented for supply. Many of the scientific apparatus and equipment required to start work in the Processing Wing of the Central Fisheries Technological Research Station were also permanently transferred to that institute. In addition, some of the films received under the T.C.M. Programme were also transferred to them and a few others to the Deep Sea Fishing Station, Bombay. Some of the other films received under the T.C.M. Programme were made available on loan for use by the Fisheries Extension Units at Mandapam Camp, Bangalore and Hyderabad. Facilities were given to the Central Electro-Chemical Research Institute, Karaikudi, for continuing their experimental observations here relating to corrosion of metals under tropical marine conditions.

The Marine Biological Association of India was inaugurated at this Research Station on the 3rd January 1959 by Shrimathi Lourdhammal Simon, Minister for Local Administration and Fisheries, Madras State. The Local Branch of the Zoological Society of India functioned effectively and several distinguished visitors addressed the members on different occasions. The Canteen and Stores, Recreation Club, Welfare Club and Ladies Club and the Nursery School, all organised and run by the staff of he Institute for the benefit of the residents of the Research Station Campus, were in active operation. The Lady Medical Officer posted at the Mandapam Local Fund Dispensary, as per special arrangements made by the Ministry of Food and Agriculture with the Madras Government had started visiting this Research Station for giving medical aid to the staff of this Institute. A list of scientific papers published by the staff during the year is appended at the end of the report.

II. Fishery Survey

The analysis of data collected in 1958 was completed during the year and the total landings of marine fish during 1958 was estimated at 7,55,774 m. tons, as compared to 8,75,516 m. tons in 1957, thus showing a decrease of about 14 per cent. below the fish landings in 1957. The production in the west coast portion of Madras particularly showed appreciable increase whereas the landings on both the east and west coast showed a general decline; while, the yield in Kerala and Mysore did not show any significant

variation. The State-war break-up of the total landings for 1957 and 1958 are given in Table I below:

TABLE I

States	Fish landings in m. tons	
	1958	1957
1. W. Bengal and N. Orissa	3,593	4,509
2. S. Orissa ..	2,674	3,757
3. Andhra ..	28,846	40,462
4. (i) Madras (East coast)	55,265	48,592
(ii) Madras (West coast)	62,791	31,092
5. Kerala ..	2,94,655	3,09,926
6. Mysore ..	80,242	76,090
7. Bombay (excluding Kutch)	2,20,906	3,56,660
8. Kutch ..	1,980	Not available
9. South Andamans ..	92	96
10. Mechanised vessels ..	4,730	4,332
	7,55,774	8,75,516

The landings in West Bengal and Orissa were lower than those of 1957 mainly due to the decline in the catches of *Harpodon nehereus*. The landings of prawns and other crustaceans, *Trichiurus savala* and sciænids, also showed a slight decrease while those of *Polynemus tetradactylus*, *Sardinella fimbriata* and other clupeids registered moderate increase.

Low catches of *Leiognathus* spp., *Anchoviella*, *Sardinella fimbriata* and *Trichiurus* were mainly responsible for the decline in the catches of Andhra. Appreciable decrease in the landings of *Upeneoides*, mackerel, *Otolithus*, *Gerres*, *Gazza*, *Hilsa ilisha*, *Sciæna* and *Ilisha* was also noticed in this State. The increase in the landings of sardines including *Dussumieria* and *Kowala coval*, *Neptunus*, prawns and other crustaceans, other *Hilsa*, elasmobranchs, pomfrets and *Chirocentrus dorab* could not balance the deficiency in the total production.

Madras State showed some increase in the landings during 1958, in spite of low catches of *Sardinella fimbriata*, *Sardinella sirm*, *Chirocentrus dorab*, *Rastrelliger*, *Thrissocles*, *Cypsilurus*, *Arius*, *Ilisha* and other miscellaneous fishes. This increase was chiefly due to good landings of *Trichiuras*, *Anchoviella*, *Leiognathus*, *Caranx*, prawns and other crustaceans. The catches of *Sciæna*, rays, *Lactarius*, *Anodontostoma*, *Upeneoides*, *Polynemus*, tunnies, oil-sardine and other sardines were also moderately good in Madras State during the year.

The slight decline in the landings in Kerala was due mainly to the low contribution of prawns and shrimps, oil-sardine, other sardines, catfishes and *Upeneoides*. Good catches of mackerel along with sharks, *Sciæna*, *Nemipterus*, *Leiognathus* and *Cynoglossus semifasciatus* were observed in these zones. Malabar coast, however, maintained steadiness in the fish production though significant decrease was found in the landings of *Sardinella longiceps*, *Trichiurus*, *Rastrelliger canagurta*, *Cynoglossus semifasciatus* and prawns and shrimps. The decline in the landings of oil-sardine and ribbon-fish was balanced by the good catches of mackerel, soles, catfishes, prawns and shrimps. The landings of *Sardinella fimbriata*, *Kowala coval*, *Anchoviella*, *Thrissocles*, pomfret, *Caranx*, *Ambassis* and sharks showed an increase while those of mullets and seer-fish showed a general decline.

The landings in Mysore during the year were slightly better than those of 1957. The heavy catches of mackerel balanced the decrease in the landings of oil-sardine, silver-bellies and jew fishes. Slight increase was also seen in the landings of soles, seer-fish, elasmobranchs, catfish, *Lactarius* and tunnies. A general decline in the landings of prawns, *Sardinella fimbriata*, *Opisthopterus tardoore* and *Anodontostoma chacunda* was also witnessed in the State during the year.

The landings in Bombay during the year were only about two-thirds of those of 1957. This was mainly due to unfavourable weather conditions which existed over a long period resulting in relatively low catches of prawns and shrimps, Bombay duck *Coilia*, *Polynemus* and oil-sardine and also to some extent decreased landings of elasmobranchs, mackerel, jew fishes, ribbon-fish and clupeids. Slight increase in the landings of eels, *Bregmaceros macclellandi*, *Upeneus*, *Leiognathus* and *Hilsa* was also found in these zones.

The fish production of Kutch region was estimated for the first time during 1958 and the catches consisted mainly of prawns. Bombay duck, *Hilsa*, *Polynemus*, *Cybium*, *Mugil*, *Sciæna*, *Arius* were also found in the catches in moderate quantities.

The salient features of 1958 were:

(*a*) The *Rastrelliger* fishery was highly successful during 1958. The total catch of *Rastrelliger* exceeded even that of 1957 and in fact was the highest since 1951. The success of the mackerel fishery was mainly due to the heavy landings of the fish in Malabar and Mysore. The fishery was also significantly good in Central Kerala.

(*b*) The landings of oil-sardine during 1958 were less than those of 1957 and this was due to the general decline in the landings in Kerala and Mysore. Some decrease was evident in the landings of other clupeoid also. The good fishery of *Anchoviella* in West Madras and the significantly increased catches of the whitebaits in South and Central Kerala are noteworthy. Some improvements were also noticed in the landings of perches, soles, eels, ribbon fish *Caranx*, *Lactarius* and *Leiognathus*.

(*c*) The landings of Bombay duck in 1958 were only a little over half those of 1957 and this decline was due to the poor fishery in Bombay owing to unfavourable weather conditions. The fishery of prawns and other crustaceans also showed a significant decline in Bombay.

The flying fish fishery in Madras was not satisfactory during the year.

The good catches of *Nemipterus* spp. in South Kerala increased the landings of perches. The landings of *Bregmaceros macclellandi* during 1958 were nearly three times those of 1957, and this is due to a highly successful fishery in Bombay.

Table II shows the overall composition of the total fish landings in India during 1958 and 1957.

Composition of fish landings

TABLE II

Name of fish	Quantity landed in metric tons	
	1958	1957
1. Elasmobranchs	24,286	23,081
2. Eels	9,159	6,397
3. Catfishes	29,872	27,379
4. *Chirocentrus dorab*	5,549	5,816

TABLE II (*Contd.*)

Name of fish	Quantity landed in metric tons	
	1958	1957
5. (*a*) *Sardinella longiceps*	1,23,731	1,91,469
(*b*) Other sardines	39,958	45,720
(*c*) *Hilsa ilisha*	991	902
(*d*) Other Hilsa	2,660	1,245
(*e*) *Anchoviella*	29,346	12,700
(*f*) *Thrissocles*	3,960	4,509
(*g*) Other clupeoids	15,525	30,663
6. (*a*) Bombay duck	67,188	1,19,500
(*b*) *Saurida* and *Saurus*	238	212
7. *Belone* and *Hemirhamphus*	348	379
8. Flying-fish	388	984
9. Perches	11,959	6,787
10. Red Mullets	2,166	3,055
11. Polynemids	5,974	14,846
12. Sciænids	25,565	29,972
13. Ribbon-fish	41,918	38,427
14. (*a*) *Caranx*	18,133	10,767
(*b*) *Chorinemus*	3,014	3,238
(*c*) *Trachinotus*	59	5
(*d*) *Coryphæna* and *Elacate*	820	423
15. (*a*) *Leiognathus*	12,865	16,909
(*b*) *Gazza*	343	958
16. *Lactarius*	16,363	8,101
17. Pomfrets	16,587	16,205

TABLE II (*Contd.*)

Name of fish	Quantity landed in metric tons	
	1958	1957
18. Mackerel	1,23,282	89,010
19. Seer-fish	7,889	8,921
20. Tunnies	3,239	3,014
21. *Sphyræna*	830	523
22. Mullet (*Mugil*)	729	1,051
23. *Bregmaceros*	3,884	1,138
24. Soles	12,856	3,687
25. (*a*) Penæid prawns	29,204	74,648
(*b*) Non-penæid prawns	55,987	61,374
(*c*) Other crustaceans	1,508	791
26. Miscellaneous	7,401	10,710
TOTAL ..	7,55,774	8,75,516

Catch per unit effort.—Table III shows the total effort in man-hours expended in each State and also the catch in kg. per man-hour during 1958–57.

The improvement in catch-per-unit effort in West Madras and Mysore even in spite of lower effort points towards greater abundance of fish. The lower return per unit effort in Bombay was probably due to lesser availability of fish resulting from unfavourable weather conditions.

III. FISHERY BIOLOGY

A. Inshore Fisheries Investigations

(1) *Oil-sardine*—Sardinella longiceps, *and other clupeoids*

(*a*) *At Karwar.*—The oil-sardine fishery showed considerable improvement during the year under review (1958–59), and the total quantity landed

TABLE III

Total effort in man-hours and catch in kg. per man-hour

	Effort in 1000 man-hours		Catch in kg. per man-hour	
	1957	1958	1957	1958
1. W. Bengal and N. Orissa	4,283	5,976	1·05	0·60
2. South Orissa ..	4,688	3,757	0·80	0·71
3. Andhra ..	47,110	50,628	0·86	0·57
4. Madras (East Coast)	46,440	46,117	1·05	1·20
5. Madras (West Coast)	27,415	20,032	1·13	3·13
6. Kerala ..	93,351	95,391	3·30	3·09
7. Mysore ..	11,495	10,809	6·62	7·42
8. Bombay .. (excluding Kutch)	82,864	79,997	4·30	2·76
9. Kutch ..	..	548	..	3·61
	3,18,147	3,13,255	2·47	2·40

was 90,706 kg. as against 37,483·2 kg. for 1957–58. However, there were frequent breaks in the fishing activity during the season which started from the third week of November 1958 and lasted up to March 1959. Oil-sardine was encountered in the *Rampan* hauls during the current season. The range in length of fish caught was 145–99 mm. with the 160–70 mm. size group dominating. Almost all the specimens examined were in the I and II stages of maturity. Studies on the length-weight relationship, sex-ratio and fecundity were continued.

The *pedi* (*S. fimbriata*) fishery commenced by the end of September and heavy landings were recorded in October, with a total catch of 11,398·9 kg. for the season. From September–November 90–99 mm. size group dominated whereas for the latter half of the season (January–March) 100–19 mm. group formed the majority of the catches.

(*b*) *At Mangalore.*—The oil-sardine fishery was a complete failure during this year in this zone and it might be significant to mention that the produc-

tion of diatoms was also extremely poor during this year. During October a small catch of oil-sardine was made at Kadike (10 miles North of Mangalore). The total length of the fish ranged from 170–80 mm. in this catch, and it is interesting to note that these fish had their gonads in stage I of maturity, giving rise to some suspicion that they might possibly belong to a second spawning generation.

(*c*) *At Kozhikode.*—The oil-sardine fishery of the 1958–59 season in the Calicut area was poorer than that of the previous season. At Vellayil, the total catch was 4,063 m. tons, while at the same place 7,700 m. tons of oil-sardine was landed from July 1957 to March 1958. As far as could be judged from the present conditions of the fishery and the size composition of the catches in the Calicut area, it would appear that there was a much lower level of recruitment in 1958–59, than in 1957–58. It may be mentioned, however, that in December 1958 and January 1959, though oil-sardine was very abundant in the fishing grounds, it was not fully exploited by the fishermen owing to fear of a possible glut in the market. From April–October, the landings were supported mostly by a single age group. This age group, along with another year-class newly recruited into the fishery, gave the catches of the November–March period. This was the year-class which was responsible for the record catches of the 1957–59 season and whose progression through the fishery was being studied from October 1957 onwards.

About 99% of the total catch at Vellayil was accounted for by *mathikolli, pattenkolli* and *mathichala vala* (gill-net). The share of the first two (boat-seines) alone amounted to about 95%. *Mathikolli* and *pattenkolli* were also the most used nets. With regard to the annual catch-per-unit of effort at Vellayil, these two nets ranked first and second respectively. All types of fishing units except *mathichalla vala* registered their highest catch-per-unit of effort during the October-December period and it would appear that the abundance of sardine in the fishing grounds off Vellayil during this period was roughly double of what it was in April–June. Of the two age groups in the fishing grounds, the *mathichala vala* fished almost exclusively the older one, and hence its catch-per-unit of effort was lower in October–December than in April–June. Oil-sardine of the commercial catch varied in standard length from 105–64 mm. (128–94 mm. in total length).

Work on the general biology of oil-sardine with special reference to the food-habits, growth and reproduction was continued at Calicut. Growth appears to be quicker during the period July–November than in other periods. The fish were mostly in maturity stages III–V in April–June and in stage V

in July–September. The samples of the October–December period contained sardines mainly in stages I and II as also some specimens in the spent and recovering spent conditions. In January and February also, sardines were mostly immature (stages I and II). Mature fish in stages IV–V were observed only between mid-May and August. The gonad-weight reached a maximum in mid-July. On 9–9–1958 a fully ripe ovary with transparent ova 0·75 mm. in diameter was recorded. Spent individuals formed the bulk of the catches in December 1958 to January 1959. Unlike last year no young fish (50–80 mm.) were observed since August 1958. But juvenile sardines (130–40 mm. in total length) were observed in December–January on certain days. The ova diameter measurements appear to show that the sardine spawns only once a year and that the spawning season is not protracted. A tendency for the females to outnumber the males was noted in the maturing shoals in May. Later the sex-ratio became more or less equal. No marked difference was found in the food habits of the smaller and bigger sardines examined. Gorged stomachs were observed whenever there was a phytoplankton bloom in the sea. This was especially noted during the monsoon months. When the zooplankton was dominant in the sea the stomachs were only half full. The fish do not appear to abstain from feeding during the breeding season.

(*d*) *At Cochin.*—Large quantities of oil-sardine (130–40 mm.) were landed in May and June. The 1957–58 season appeared to have ended with the small and irregular fishery for 140–60 mm. groups in July. The entry of juveniles (130 mm.) in August indicated the starting of the 1958–59 season. The appearance of another immature but large-sized group (170 mm.) contributing significantly to the fishery from September–December is of great interest from the point of population studies. Maturity studies revealed the occurrence of a good number of specimens in stage III and of some in stage IV from May–July. A few recovering spent fishes (stage I) were met with in the third quarter, especially in October. Sex-ratio studies have shown the female to exceed the males in number, the former constituting about 60%. Oil-sardine eggs were collected for the first time from this area (76° 09′ 8″ E., 09° 58′ N.).

A method has been developed to distinguish the sex of the oil-sardine externally. In the males a prominent muscular urinogenital papilla is present whereas in the female fish the genital and urinary openings are situated on a thin-walled protuberence. On the basis of this external difference sexes can be easily distinguished in the field so as to help in handling large samples of oil-sardine for sex-ratio studies.

(*e*) *At Neendakara.*—Biological studies on oil-sardines were started at this centre. Preliminary observations indicated that the fish obtained in the local catches belonged to the first and second stages of maturity. The gut contents of a few specimens from each sample have been analysed.

(*f*) *At Mandapam.*—The *choodai* fishery commenced in Palk Bay in June and lasted till October. The fishery started in the Gulf of Mannar from November onwards. *Sardinella albella* predominated the catches from Palk Bay while in the Gulf of Mannar *S. gibbosa* was the dominant species. Appreciable landings of *S. gibbosa* were observed in January and February from the Gulf of Mannar. Data were collected on various meristic and morphometric characters and on the intestinal length, for detailed taxonomic studies.

(*g*) *At Waltair.*—A fall in the landings of sardines was noticed at Lawson's Bay during the period from April 1958 to March 1959 as only 34·28 m. tons were landed compared to 87·50 m. tons of the corresponding period in 1957–58. The sardine fishery of 1958–59 season started in October. Shore-seines were operated from December onwards. A total of 33·16 m. tons of sardines were landed during October–March of which 93·46% were landed by gill-nets, 6·4% by shore-seines and the rest by boat-seines. A gradual increase in the fishery was observed from October–December. There was a decrease in the landings in January and February and a rise in the month of March. The highest catch of 21·56 m. tons was recorded in March. *Sardinella fimbriata* was the dominant species of sardines in the catches throughout the season and the fishery was mainly contributed by juveniles. *Sardinella gibbosa* was caught in small quantities in April and from October-February.

Studies on the biology of sardines started in 1957 were continued during this year. A detailed analysis of the gut-contents of *Sardinella gibbosa* was made. *S. gibbosa* obtained in April and May ranged in size from 57–117 mm. and they were all juveniles. From October–January the size-range was 124–59 mm. and the fish were in stage I of maturity while in February 1959, 138–62 mm. fish occurred in the catches which were in stages I–IV. Gut-contents of 210 specimens of *Sardinella fimbriata* in different size-groups were analysed. Most of the specimens examined during October–March were juveniles. Specimens in stage I of maturity were recorded during December–March. The size-frequency distribution of the catches showed two peaks in each of the three months of October, November and December. In October they were at 55 and 90 mm., whereas in November they were around 65 and 115 mm. while in December they were at 75 and 120 mm.

The dominant size-groups recorded for January, February and March were 95, 105 and 120 mm. respectively. Certain morphometric and meristic characters were studied in some of the samples of *S. fimbriata*.

(2) *Mackerel*—Rastrelliger canagurta

(*a*) *At Karwar.*—Length frequency studies of the Indian mackerel showed that the fishery in October and early November was composed of the 190 and 200 mm. groups. From the second week of November to the third week of March, the mode remained constantly at 210 mm. During the last week of March the 220 mm. group was dominant. Thus from October–March there was a shift in the mode from 190–220 mm. The ratio of females to males varied slightly from month to month, although the overall ratio for the year was 50 : 50. The fishery was composed of immature fish. Observations appear to indicate that the mackerel has only one spawning period lasting from May or June–January or February, with a rather short time interval in the ripening of successive batches of ova. Whether this spawning occurs with a regular and continuous shedding of ova or whether there is any interval between the release of successive batches, in view of the long duration, needs further investigation.

(*b*) *At Mangalore.*—Fishery for mackerel along the coast started somewhat late this year as against the previous years when the fishery was evenly spread out during the season. This year there were spurts of very active fishery followed by long periods of lull. However, the fish caught even in the beginning of the fishing season belonged to the larger size-group (210–19 mm.). Mackerel caught during the active fishing seasons were all juveniles and immature. The volume of the stomach contents was relatively high during November, when it consisted mostly of copepods.

(*c*) *At Kozhikode.*—This year's mackerel landings at Calicut were 1,449·78 m. tons out of the total fish catch of 7,437·38 m. tons, thus contributing 19·49% to the annual catch. The fishery was contributed by one dominant class (215 mm.) which persisted throughout the season. Mackerel caught in April–September months were in maturity stages III–V and those from October–March in stages I–III. The juvenile mackerel up to 160 mm. encountered in September were in stage I.

(*d*) *At Cochin.*—Mackerel fishery at Cochin was of small magnitude. With moderate landings of 200–20 mm. group in April the 1957–58 season ended. The 1958–59 season started in September and continued till January when it showed decline. The 190–210 mm. group mainly supported the fishery. Landings were mostly by gill-nets. At the end of the previous

season in April and May specimens in maturity stages II and III were encountered whereas still advanced stages were rare. Ova diameter studies of stage III ovaries showed a unimodal curve.

Active feeding occurred more or less during the entire period except during the first quarter when it was only moderate.

Cursory examination of the otoliths showed only a very small percentage of the fish above 210 mm. which possessed demarcations like growth-zones.

(*e*) *At Vizhingam.*—There was no exclusive fishery for mackerel along the Vizhingam coast, during the year. However, mackerel were caught in small numbers throughout the year along with other fish, in shore-seines, boat-seines and drift nets. The total landings of mackerel at Vizhingam for the year were estimated at 15,500 kg. The size composition of the fish in these catches showed four different size-groups during the first quarter of the year (within a wide size-range from 40–240 mm.) while towards the last quarter adults of 225–45 mm. in total length dominated.

The bulk of the catches consisted of either indeterminate or immature fish. A few specimens obtained in August–October showed their gonadial maturity in stages ranging from I–VII. Detailed studies on the spawning of the species are being made. Analyses of plankton collections of the previous two years have been made with special reference to the eggs and larvæ of mackerel.

(*f*) *At Mandapam.*—The mackerel fishery of the Mandapam area was poor during the year and there were no landings at Vedalai fish landing place. Occasional samples were, however, available from other neighbouring villages during the months of April, May and November–February. There was no fishery during the period June–October after which the fishery in the area started in the last week of November. The size-range during the different months was as follows:

Month	Size-range (total length in mm.)	Remarks
April ..	207–312	Largest sizes were few and unusual. Ripe and spent individuals were frequent.
May ...	220–236*	
November ..	201–235	*Five specimens only.
December ..	192–230	Mostly in stage I or II of maturity.
January ..	191–235	
February ..	202–244	

Studies which were initiated at Karwar on the scale-rings in the Indian mackerel were continued. The analysis of the data relating to 369 specimens from North Kanara indicated that these rings were spawning marks occurring as a rule in the older individuals and that they might prove useful not only in age and maturity studies but also in raciation studies in view of the reported variation in the size-distribution and spawning period of the species in different parts of the Indian coast. In continuation of these observations scale studies on mackerel from the Indian coast were carried out. Sufficient numbers of the larger sizes of fish were, however, not available.

Of the morphometric data collected in the past, certain selected characters were utilized for the analysis of co-variance in order to test the distinctness or otherwise of the populations from different centres. Of the meristic characters the positions of certain vertebral characters were studied. The data taken related to samples drawn from Ratnagiri, Karwar, Malpe, Kozhikode and Mandapam.

Several samples of *Rastrelliger* were received from abroad during the year. Observations on these samples have been in progress and certain morphometric and other data have been collected on most of these samples for comparative study with the Indian material.

(*g*) *At Porto Novo.*—Mackerel formed only 9% of the total fish landings at this observation centre. *Rastrelliger* ranked second to *Lactarius* in importance. Mackerel fishing on the coast is restricted to two very short seasons, namely, August–September and January–March. The size composition of the fish caught in the first season varied between 140 and 170 mm. and in January–March between 200 and 240 mm. During both seasons, a slight preponderance of the females over the males was noticed with a ratio of 6 : 5. Studies on the sexual maturity of the fish indicate a possibility of the fish attaining first maturity at about 200 mm. in length. This seems to be in agreement with observations made on the west coast. Similarly, gonadial studies indicate that the first spawning takes place in April or May. Efforts to identify mackerel eggs in the plankton or to fertilize the eggs artificially were not so far successful.

(3) *Biology and fishery of prawns*

(*a*) *At Bombay.*—This year a total of 79 samples was taken from Bombay out of which 36 were collected from Versova, 23 from the vessels belonging to Deep-Sea Fishing Station, Bombay, and 20 from the trawlers belonging to New India Fishing Co. The principal species of prawns in Versova landings were *Metapenœus affinis*, *M. brevicornis*, *Parapeneopsis sculptilis*

and *Solenocera indicus*; whereas in the previous year they were *M. affinis*, *M. brevicornis Parapeneopsis stylifera*, *P. sculptilis* and *S. indicus*. *P. stylifera* has disappeared from the catches both at Versova and Sassoon Docks; a species of the genus *Trachypenæus* has been recorded for the first time. They were encountered in comparatively large numbers. Studies of year-class strength, rate of growth, sex ratio and sexual development of the prawns (from Bombay) are being carried out through sampling the commercial catches. The size composition of the Versova samples was more or less similar to those of the Sassoon Docks (Area 43 A). However, there was a remarkable difference on the species comprising the catch and the size composition of the catches landed by New India Trawlers. It is evident from the present study that the sex-ratio tends to vary with age and the species, with the season, and probably with the ground also. It varies from slight predominant male population to a complete female population. However, it appears that more information relating to the problem is required before further analysis is given. In general, immature prawns formed a large proportion of the commercial catch at all the three centres.

(*b*) *At Mangalore.*—Prawn fishery by the indigenous craft was poor this year as in the previous year. October–November period was the peak season. Cast-net was the chief gear used and the catches consisted mainly of *Metapenæus dobsoni*. *Kanthabale* operated from January–March landed poor quantities of *Penæus indicus*. A good number of berried females were observed during October and this coincided with the occurrence of large number of prawn larvæ in the plankton.

The mechanized vessels of the State Fisheries Department started operations from the last week of September. From September–January there were no prawn catches but from February, the catches were fairly good and comprised of *Metapenæus dobsoni*, *M. monoceros*, *M. affinis*, *Penæus indicus*, *Parapenæopsis stylifera*. Mostly *M. dobsoni* dominated and the most abundant size groups for females ranged from 86–90 mm. and 91–95 mm., while for males they were 76–80 mm. and 81–85 mm. Males outnumbered the females in most of the catches. Data on percentage composition of the catches, length-frequency, sex-ratio and maturity conditions were recorded. Juveniles of *M. dobsoni*, *M. monoceros*, *P. indicus* and *P. canaliculatus* were caught in appreciable quantities in the Netravati estuary.

(*c*) *At Kozhikode.*—Along the Calicut coast prawn fishery showed marked fluctuations during the period under report. The fishery was absent in June, October, December of 1958 and January and February of 1959 due

to the existence of more lucrative sardine and mackerel fisheries. During monsoon months fishing was totally abandoned on several days but whenever there was fishing the return was substantial. *Paithuvala, pattenkolli vala, arakolli vala*, cast-net and otter trawl at Beypore were employed during this period. The first three are boat-seines operated in waters up to 20 metres deep. Cast-nets were employed when the fishery was at its minimum. The fishery was at its peak during the monsoon period when the landings amounted to 193 m. tons for three months at Calicut and 493 m. tons for the same period at Quilandy. Moderate fishing existed from April–June when 14·31 m. tons at Calicut and 5 m. tons at Quilandy were landed. The October–December period witnessed a fall in the fishery when sardine and mackerel fisheries were flourishing and the landing figures were 5 m. tons at Calicut and 11·9 m. tons at Quilandy. The fishery was a failure during January and February 1959.

M. dobsoni was the most important species in the catches, especially in the monsoon period. During the other months, April and May, this species accounted for 50–90% of the catches. *Parapenæopsis stylifera* was the next in importance, the peak for this species being in May and July and it reappeared in February. *Penæus indicus* occurred only in small quantities throughout and a slight increase in quantity was noticed towards the end. *M. affinis* was noted for its demarcated seasonal occurrence. A slight increase in their numbers was noticed towards the end of the year under report.

Eggs and larvæ belonging to the species *M. dobsoni* were observed from November–December. Some attempts were made to rear the protozoea and zoea stages in the laboratory.

(*d*) *At Cochin.*—The fishery was quite poor on the Cochin coast and catch samples for routine study were not available in some months. At Alleppey, excepting for the failure of the fishery of *Parapenæopsis stylifera*, the same trend as has been noted last year is seen this year also. *M. dobsoni* contributed to the major portion of the catches in all the months. In the months of the peak season the percentage of the species increased considerably, the size of the prominent length group also reached the maximum, and males were represented in the catches more than females. Although *P. stylifera* comes next in abundance, its percentage was much lower than that of last year. *M. affinis* was the next predominant species and it showed an increased percentage in some months, especially in November.

At Chellanam, in the case of the dominant species *M. dobsoni*, the same trends are noted as at Alleppey, the percentage and the prominent length

groups being at the maximum during July–September. In these months the males are in excess of females. *M. affinis* and *P. indicus* are next in abundance. The prominent length group of *M. affinis* increased regularly from 81–85 mm. to 131–35 mm. At Narakkal, although sufficient samples were not available in all the months, in the case of *M. dobsoni* the same trend of maximum percentage and prominent length group in September is noted.

In the country craft catches of Alleppey and Narakkal *M. dobsoni* is predominant and *P. stylifera* next in abundance, whereas in the trawler catches *M. dobsoni* is dominant and the species next in abundance is *M. affinis*. The latter is the case in the country craft catches of Chellanam also, which is slightly in variation from data obtained last year. In regard to the recruitment of post-larvæ to the backwaters, in comparison with last year, a marked increase in the species *M. dobsoni* and *M. monoceros* and decrease in *P. indicus* has been observed this year.

In the trawler catches also *M. dobsoni* is the major species in most of the months and bigger size groups were represented in the catches, as has been noted last year. In repetition of the observation of last year *M. affinis* is the species next in abundance this year also. This is more prominent this year since in November and December this is the dominant species. The prominent length group of this species increases from 81–85 mm. to 131–35 mm. by the end of the year. A slight difference between the catches of the shrimp trawlers and that of M.T. 'Ashok' and 'Pratap' is noted in that in the former *M. dobsoni* is dominant and in the latter *M. affinis* or *P. indicus*.

The quantitative observations that were being made on the catches of two stake nets, one at Azhikal near the harbour mouth and the other at Thevara about 5 miles to the south were stopped at the close of October after collecting data for two years. They are being analysed in order to show the fluctuations in the total catch of prawns from month to month as well as the variations in the proportion of the species represented and their size-range. The catches were generally much less in 1958 when compared to those of 1957 at both places.

The statistically designed experiment on paddy field prawn fishery with a view to ascertain, if any, the effect of area of the field and size of sluice on the annual yield came to a close in April. When the catches from the various sections of the field were compared it was found that, (*i*) two sluices did not affect any substantial improvement in the yield over only one, the area of the field remaining the same, and (*ii*) the yield from the larger field is larger irrespective of the number of sluices provided and is roughly pro-

portional to the area of the field. The experiment is being repeated during this season also in order to verify last year's results.

Last year's experiments on *Tilapia* plus prawn culture showed that the fish does not usually feed on prawn fry and young ones. The experiment is repeated this year to verify this and also to establish, if any, the effect of the presence of prawns on the growth of the fish. Observations made so far seem to indicate that growth is slightly retarded.

(4) *Half-beaks*—Hemirhamphus *spp.*

There were good landings of Hemirhamphids in the Mandapam area during the period under report. The fishing operations at Theedai commenced in the first week of March, slightly earlier than the previous year. Morphometric measurements and meristic counts were taken of all the samples received from the various survey centres. The morphometric data have been completely analysed while the meristic characters remain to be studied. Samples of *H. georgii* from the Gulf of Mannar and Palk Bay are being compared for detection of possible differences. The data for the males and females from one locality (Rameswaram) have been analysed separately and no statistically significant difference has been noticed between sexes for the four characters chosen. The seasonal variation in the diet of *H. georgii* seems to have some physiological relation with the maturation cycle. It has been observed that there is no complete cessation of feeding in any species of *Hemirhamphus* during its spawning period in this area. Maturity studies are in progress. Large samples were sexed on various occasions in the field in the case of both *H. georgii* and *H. marginatus* in order to get a clear picture of the sex-ratio of the spawning population of the two species. The spawning ground of *H. marginatus* in the Gulf of Mannar has been located. Attempts to rear the eggs in the laboratory were a failure.

(5) *Seer-fish*—Scomberomorus guttatus

Studies on the biology of *Scomberomorus guttatus* were continued at Waltair. The total landings of the fish for the period at Lawson's Bay were estimated at 59·0 m. tons. The fishery reached its maximum in June, with a sudden decline thereafter. In December again it reached another peak. Teleosts, crustaceans and molluscs which formed the main food of the fish constituted 18%, 21·5% and 0·84% respectively the stomach contents on an average for the year. Among crustaceans squilla larvæ were the most important item while larval and young prawns were also present. Cephalopods and gastropods were observed rarely. The percentage of females was

always higher than that of males. Length-frequency analysis showed that 320–60 mm., 360–400 mm., 400–40 mm. and 440–80 mm. size-groups were dominant in different periods. From February–October, fish of 600 mm. size and above were recorded. Juveniles of 30–110 mm. size were observed in March.

(6) *Mullets*—Mugil *spp.*

The following observations were made on *Mugil cephalus* and *Liza macrolepis* of the "Pullamadam" backwater area (near Palk Bay) which had been taken up for detailed biological study. Two distinct size-groups of *Mugil cephalus* (100 mm. and 260 mm. in furcal length) occur in the lagoon catches in January. The larger group dwindle in numbers since February, and disappear completely by the end of March while the smaller size groups continue to show steady progress in growth and are regularly caught in the nets. None of the specimens examined had any well-formed gonads excepting two fish in September (at 229 mm. and 243 mm. furcal length) and one in November (at 233 mm. furcal length) which had gonad in stage II of maturity. Nematode parasites were observed in the body cavity of this species.

The size-range observed in the catches of *Liza macrolepis* was between 69 and 320 mm. furcal length. The smaller sizes occurred in the catches in June, July, September, December and January. Mature (about stage IV) and spent fish were observed during early June, middle of August and December, but these were more commonly seen in the cast-net catches from the Palk Bay. Studies on food, maturity, time and duration of spawning (by the availability of the fry) and rate of growth of the two species are in progress.

(7) *Tunny*—Katsuwonus pelamis

Investigations on the biology of the tuna, *Katsuwonus pelamis*, which forms the more important species of tunnies (the other being *Neothunnus macropterus*) around Minicoy Island, were started during this year. The fishing season commences early in November and lasts till about April and the fishing activity is usually within a range of 6–7 miles around the island. The export of dried tuna in 1958 amounted to about 173 m. tons as against 281 m. tons in 1957.

The commercial catches are usually composed of fish ranging in size from 390–690 mm. in standard length and with an individual weight varying from about 1–6 kg. Nevertheless, specimens of a minimum length of

290 mm. and those as large as 1,239 mm. were recorded in this region. Adult fish which are mostly mature or spent constitute the fishery. Preliminary observations indicate that spawning commences in February. There is generally a preponderance of males in the catches at the beginning of the spawning season. Fecundity and ova diameter studies are in progress. A general survey of the tuna live-bait fishery was carried out because of its importance in the tuna fisheries programme.

(8) *Spiny lobsters*—Panulirus *spp.*

Because of the growing economic importance of the spiny lobster fishery along the coast of Kerala biological observations on the fishery was started towards the end of the third quarter of the year under report. The fishery of the Kanyakumari District is richer than in other regions. The total catches in numbers at Colachel and Muttam during the 3 months December–February have been estimated as follows:

	Colachel	Muttam
December (15th–31st) ..	19,958	53,645
January ..	19,292	36,661
February ..	9,306	9,200

Three types of gear were in use in the Muttam area, *viz.*, the anchor hook, the trap and the gill-net. Except in February anchor hooks were not used at Colachel. In this place the major part of the catch has been obtained by the trap while at Muttam, the catch by the anchor hooks were much higher, except in February, as the following figures will show.

	Trap	Net	Anchor hook
At Colachel—			
December ..	16,398	3,560	Nil
January ..	16,228	1,064	Nil
February ..	9,306	50	50
At Muttam—			
December ..	7,359	Nil	46,286
January ..	14,672	Nil	21,989
February ..	6,932	58	2,210

Although four species were represented in the catches one of them predominated and in all the months had contributed practically the entire catch, the other species accounting for only 1–2%. The estimates of total catches given above therefore relate only to this species which is provisionally identified as *Panulirus dasypus.*

Length-frequencies have been determined separately for each sex of this species for each centre; the sex proportions have also been determined. At Colachel the proportion of males was 63·7% in December and 53·3% in January. At Muttam the percentage varied from 61% in December to 46·4% in February.

(9) *Molluscs*

Investigations on the effect of transferring seed clams, *Meretrix casta*, from the Adyar estuary to the Cooum estuary have shown that the depleted clam beds could be reclaimed by transplanting young clams during the October–November period when the hydrological conditions in both the estuaries are identical. The polluted nature of the Cooum estuary during the rest of the months appear to affect the transferred seed clams adversely. The large-scale occurrence of young ones of *M. casta* measuring 1–5 mm. with a mode at 3 mm. during the months of April indicated that these clams probably spawn sometime towards the end of March. Studies on the rate of growth of these clams in relation to the variations in the environmental factors, such as pH, salinity, phosphates, silicates and nitrites, were continued.

Training in the modern methods of diving with aqualung, etc., was undergone during the survey of the chank beds and pearl oyster paars off Tuticorin conducted by the Madras Fisheries Department in collaboration with Dr. F. B. Salvadori, F.A.O. Underwater Expert. So far, three paars, *viz.*, Davi paar, Fernando paar and Velangu Karuwal paar, have been surveyed in detail and the survey of the Tholayiram paar is in progress.

B. Offshore Fisheries Investigations

(*a*) *Mechanised fishing at Bombay*

During the year under review the analysis of the catch data from the trawlers of Government of India and New India Fisheries was continued. In addition, the fishery and biology of *Dara*, *Ghol*, *Koth*, *Karkara*, *Shende*, Bombay duck and prawns were studied.

The two sets of bull-trawlers Arnalla and Paj and Satpati and Pilotan of the New India Fisheries Ltd., Bombay, have taken 3,529 hauls and landed

36,15,648 kg. of fish and shellfish from January–December 1958. There has been an increase of 12·64% in the total quantity of fish taken in the areas fished and increase of 20·53% in catch per haul, when compared with that of last year. The increase in catch per haul, in the areas fished, has been during the months of January, March, April, July, August, September, October, November and December and was of the order of 13·74, 11·11, 14·30, 5·34, 9·95, 53·83, 67·01, 85·80 and 28·17% respectively. The decrease in catch per haul during February, May and June was of the order of 11·57, 3·95 and 20·29% respectively. The major groups of fish landed in their order of abundance together with their percentage composition in the total bull-trawler takings has been—*Sciæna* and *Otolithus* spp. (21·283%), *Murænesox talabonoides* (15·081%), sharks (10·300%), *Arius* spp. (8·453%), *Pellona* spp. (5·558%), *Pristipoma* spp. (5·413%), *Lactarius delicatulus* (5·190%), *Sciæna diacanthus* (4·838%), *Polynemus heptadactylus* (4·500%), *Polynemus indicus* (2·295%), skates and rays (1·936%), *Pagrus spinifer* (1·916%), miscellaneous (1·805%), *Sciænoides* spp. (1·740%), and other nineteen minor groups which together constitute 9·692%. There were eight mechanised vessels of the Deep-Sea Fishing Station operating from Bombay. In the month of October 1958 three boats were transferred to Cochin. From November, two boats have started working off Veraval. Totally 492 voyages were undertaken and 1,542 hauls made involving 2,804 hours and 20 minutes of actual fishing effort. The total landings were 3,00,576 kg. and an average catch of 107·182 kg. has been obtained. The major groups have been Sciænids (32,688%), skates and rays (27·760%) and catfishes (6·775%).

(1) *Biology and fishery of* Dara—Polydactylus indicus.—The preliminary study of *Dara* from the landings of the bull-trawlers indicates that areas around Lashington Shoals off the Gulf of Cutch, abound mostly in juvenile fish while adults are found only in small numbers. However, as the season advances an extensive gill-net fishery for these occurs off the coast of Jamnagar and Satpathi. Investigation started at these two centres are expected to throw some light on the movements of the juveniles and adults. The peak period of *Dara* fishery is January–March. From April–August there is a decline followed by a gap in our observations in September due to the stoppage of operations by the trawlers in this area on account of unfavourable weather conditions. From December onwards there is a recovery in *Dara* fishery. The bulk of the landings from the bull-trawlers consists of *Chelna* or juvenile *Dara*. The size-range vary from 290–975 mm. during April–June and specimens from 700–800 mm. were immature (stages I and II). One *Dara* of 975 mm. was found to be at stage IV of maturity

in June but two specimens of 980 and 1,020 mm. taken in December were found to be at stage III of the spent recovering phase.

(2) *Biology and fishery of* Shende—Polynemus heptadactylus.—Locally *P. heptadactylus* is landed by dol or bag-net and it consisted mostly of individuals less than 900 mm. in length. They were all immature and in many cases even the sexes could not be differentiated. Only in October and November slightly larger specimens in the stages I and II of maturation were observed. The smallest size-group with the mid-point at 200 mm. entered the fishery twice in the year, in September and March. The New India Fisheries Trawlers landed fishes of above 950 mm. size. Spent individuals were observed nearly for 8 months. Spawning individuals were noticed twice in the year, July and March. This fishery formed 4·7% of total trawler landings in the offshore areas of Cambay, Porbandar and Dwaraka.

(3) *Biology and fishery of* Ghol—Pseudosciæna diacanthus.—This fishery formed 4·38% of the landings of the New India Trawlers which operated mainly in Dwaraka, Porbandar, Veraval and Cambay regions. The trawler catches consisted of fishes of length range 200–1,060 mm. though the dominant size-groups during the months fluctuated between 325 and 975 mm. In the inshore catches of dol-net at Versova, however, juveniles of 320 mm. were available in large numbers especially from October–March, though a few larger fish (1,110 mm.) than those occurring in trawlers were also recorded. The length at first maturity appears to be between 800 and 850 mm. spent and spent recovering fish were found during October–March in large numbers. From April onwards mature specimens (stage IV) were recorded, reaching stage V in June as seen from examination of the few available specimens. Scale and otolith studies are inconclusive, as the growth checks are not distinct, though some indications of zonation can be seen in the scales and up to seven rings could be made out in fish of 1,000 mm. Further work is in progress. Examination of stomachs shows that 60–70% are empty due to extrovertion of the stomachs while landing the fish, especially of the large ones. In the stomachs, which were not affected, prawns, shrimps and small fishes were found, the crustaceans being found in greater quantity in the young *Ghols*, and fishes dominating the gut contents of the larger fish.

(4) *Biology and fishery of* Koth—Sciænoides brunneus.—The bull-trawler landings of *Koth* became reduced from 2·71% of total catch in 1958 to 1·74% in 1959. They were mainly caught in the offshore region off Dwaraka. The fishery is formed mainly of juveniles above 250 mm. length. In the dol-net catches of the inshore waters, however, the size-range from 750–1,250 mm. do not appear at all. Prawns and fishes form the major

food items of the fish. They seem to prefer *Acetes*, *Bregmaceros* and *Coilia* during monsoons. In winter months feeding activity is at the minimum whereas it is maximum in May-October. The fish attains first maturity at 1,200 mm. Spawning takes place probably from January. Fecundity was found to be around 6·8 million eggs per female. Scale and otolith studies show 3–4 growth checks on the former tallying with the length-frequency modes in monthly samples of fishes within 1,000 mm. range. 10–11 rings were found on scales of specimens 1,450–1,500 mm.

(5) *Biology and fishery of* Karkara—Pomadasys hasta.—Biological study on *Pomadasys hasta* locally known as *Karkara* was continued. The fish is mainly landed by trawlers constituting 5·41% of the total catch. November–December seems to be the good months for this fishery especially in the Porbandar and Dwaraka regions. The fishery gradually declined from the month of March–September and started recovering in October. Juveniles of *P. hasta* ranging from 54–125 mm. in length were collected in January. They are caught by a type of gill-net locally called 'peri' which is operated near the shore. Otoliths of 200–320 mm. size-group fish show two rings, 330–440 mm. three rings, 450–560 mm. four rings and 570 mm. and onwards five rings. Scales also show some rings on them but their interpretation has not been possible. Stomach analysis reveals that it feeds on squilla, crabs, prawns, sipunculids, polychæte worms, lamellibranchs and gastropods. From the above it seems that *P. hasta* is a bottom-feeder. Juveniles are plankton feeders mainly feeding on amphipods. For maturation study nearly 250 specimens were examined. Females constituted 48·13% and the rest by males. In the month of June ovary shows IV stage of maturity. Occurrence of spent specimens started from October–December. From this it appears that spawning may be taking place from September–November which is again supported by the occurrence of juveniles in January.

(6) *Biology and fishery of* Bombil—Harpodon nehereus.—Length-frequency studies at two fish landing centres at Bombay have shown that the recruitment to the stocks takes place during November–December. The rate of growth appears to be 12–15 mm. per month in the earlier life of the fish. The rate of growth progressively decreases in the later life and is about 4 mm. per month in specimens beyond 250 mm. The commercial catches mainly comprises of fish measuring between 190 and 250 mm. Spawning season of *Harpodon nehereus* appears to commence in December and lasts till the end of February. With the available data on hand the minimum size at maturity is 217 mm. The number of eggs that can be produced by a single individual has been estimated to vary between 14,606 and 81,205.

Ova diameter measurements have shown that the development of ova in all the regions of the ovary is uniform and that a single individual spawns only once a year. Considerable volume of data for raciation studies has been collected and is being processed statistically.

(*b*) *Mechanised fishing at Cochin*

"*Ashok*" *and* "*Pratap*".—In April 1958 the cutters 'Ashok' and 'Pratap' in the course of bull-trawling in area 108 in depths ranging from 24 to 44 m. close to Cochin, obtained a total catch of 76,965 kg. over a trawling time of 52·63 hours, the catch per trawling hour being 1,462·38 kg. Both the total catch and the catch-per-unit effort were the highest recorded for any one month during 1957–58 season. In May 1958 also the fishing operations were mostly confined to area 108 at depths ranging from 18 to 46 m. and the total catch amounted to 75,972 kg. over a trawling time of 55·7 hours, the catch per trawling hour being 1,363·93 kg. During both the months small fish formed major part of the catch (73·31%) while the other important fishes in the landings were rays (11·93%), sharks (8·89%), catfish (2·33%) and *Pristipoma* (1·79%). The high catch rates obtained in April and May 1958 show that area 108 is a rich fishing ground, though the bulk of the catches belonging to small fish category. In June the total landings declined to 25,416 kg. due to adverse weather.

In January 1959 the cutters resumed bull-trawling operations after the monsoon break in areas 108, 110, 111 and 112 lying between Quilon and Cochin at depths ranging from 24 to 47 m. The total catch for the month was 54,737 kg. over a total trawling time of 89·62 hours, the catch per trawling hour being 610·77 kg. The highest return per unit of effort, 722·02 kg. per trawling hour, was from area 111. In February 1959 the trawling operations were mostly confined to area 108 and the total catch obtained was 29,743 kg. over a trawling time of 55·50 hours, the catch per trawling hour being 535·9 kg. In both the months small fish constituted the biggest catch (42·09%), while rays (24·76%), sharks (15·89%), *Pristipoma* (6·97%), moonfish (3·64%) and prawns (2·99%) were the other important categories in the landings.

'*Durga*'.—During the year this trawler carried out shrimp trawling mainly in areas 106 A and 108 close to Cochin. In April and May 1958 the total catch amounted to 18,587 kg. over a trawling time of 172·58 hours, the catch per trawling hour being 107·70 kg. Small fish (47·66%) and prawns (38·81%) formed the major catches. All the vessels suspended fishing operations during June–November period for the duration of the monsoon and carried out annual repairs. The total landings during

December 1958 to February 1959 came to 34,054 kg., the highest catch of 14,019 kg. being recorded in the month of February. Prawns formed the dominant catch (47·44%) while small fish (37·33%) was the next major category in the landings.

'*Samudra*'.—This trawler which commenced fishing operations off Cochin in April 1958 operated shrimp trawl, mainly in area 108, at depth ranging from 7·27 m. The total catch in April and May 1958 was 5,982 kg. the catch per trawling hour being 41·98 kg. Small fish formed the largest portion of the catch (57·07%) while prawns formed the next large category in the landings (36·79%). In June the total catch was 3,037 kg., prawns constituting the dominant catch (67·88%). The total landings during November 1958 to February 1959 were 40,240 kg., the catch per trawling hour being 111·78 kg. Small fish (55·45%) and prawns (32·79%) constituted the main catches.

'*Tarpon*'.—This vessel started fishing operations off Cochin in May 1958 and like the other small vessels, she operated shrimp trawl mainly in area 108 at depths ranging from 11 to 27 m. The total landing in May 1958 was 8,427 kg., the catch per trawling hour being 82·62 kg. Small fish (47·95%) and prawns (39·93%) formed the main catches. During October 1958 to February 1959 the total landing amounted to 41,335 kg. (the highest among smaller vessels), the catch per trawling hour being 110·70 kg. Small fish (59·92%) and prawns (30·49%) were the main catches. In all the above vessels the maximum landing of prawns was in January 1959.

'*Sagarkumari*'.—This vessel commenced fishing operations in area 103 off Cochin in October 1958 and during October 1958 and February 1959 a total catch of 19,272 kg. was obtained. As observed in the other vessels, here also small fish (43·48%) and prawns (41·83%) were the main categories caught.

(*c*) *Mechanised fishing at Calcutta*

The details of catches by the Government of West Bengal's trawlers for the year under report was collected entirely from the landing place. Out of five trawlers, Kalyani II was inactive throughout the year, Kalyani I had 7 fishing voyages and in one voyage there was no fishing. The total catch by this trawler was 81,643 kg. for only six trips and thus worked a better average catch per voyage than Kalyani III which in its eight voyages could

Name of vessel	No. of voyages	A in kg.	B in kg.	C in kg.	Total
Kalyani I ..	7	323·02	81,096·01	224·08	81,643·11
Kalyani III	8	1,400·26	84,326·03	2,156·86	87,883·15
Kalyani IV	6	1,150·31	53,410·02	2,873·08	57,433·41
Kalyani V ..	11	2,419·43	57,966·36	3,254·60	63,640·39
TOTAL..	32	5,293·02	2,76,793·42	8,508·62	2,90,600·06

take 87,883·15 kg. The lowest total of 57,433·41 kg. was obtained by Kalyani IV. Though the number of voyages made by Kalyani V was more, the total catch of 63,640·39 kg. worked out a comparatively low average catch per voyage. There was no fishing during the months of May–July, and only one voyage was possible in August and September. Improvement in the catches was noticed from October onwards with the maximum returns in January, confirming the observations made in previous years regarding fishing trends. In the absence of master's log reports the exact fishing grounds where particular types were taken could not be ascertained. It was in a general way information gathered about fishing grounds visited, from the masters after the arrival of the vessel. The change in the method of catch disposal where transference from fish holds to shore cold-storage immediately after the vessels berthing did not allow a more detailed appraisal of the catch composition. The increased types in various classes listed here may indicate improvement of the fishery in a general way though actually there was fall in the total quantity landed over previous year. Presence of seer-fish, mackerel and better valued perches may be taken as an encouraging sign for further activity. Especially when commercial exploitation is the main object, attempts for greater effort may prove more profitable. Presence of smaller quantities of better class and B class perches, seer-fish, horse mackerel and an increase in clupeid and eel catches are the special features of the catch composition of this year's landings. The last two voyages in March, when fishing was confined to nearer fishing grounds, produced good quantities of eels. A decrease in the taking of sciænids (Bhola) and glass fish (*Kurtus indicus*) was noticed, though they continued as in previous years to be the main varieties. It was gathered that fishing was mainly concentrated near Black Pagoda, Devi and Prachi river-mouth up to False point and during rough weather limited operations were con-

ducted near Hoogly point and Sand heads. Total landings of individual types compiled at landing place are given below:

		kg.	kg.
A.	Prawns and shrimps:		
	Metapenæus	152·02	
	Penæus	1,105·88	
	Acetes	96·16	
			1,354·06
	Pomfrets		1,302·32
	Perches:		
	Pristipoma sp.	2,400·33	
	Ephinephelus sp.	28·58	
	Nemipterus sp.	12·70	
	Lates calcarifer	111·58	
	Indian salmon	37·20	
	Otolithus sp.	1·81	
			2,592·20
	Mackerel		7·25
	Seer-fish		37·19
			5,293·02
B.	Sciænids		1,09,034·90
	Glass fish (*Kurtus indicus*)		84,318·92
	Clupeids:		
	Pellona sp.	20,527·43	
	Setipinna sp.	2,250·75	
	Engraulids	5,388·27	
	Other clupeids	5,388·27	
			28,783·91
	Silver belly		14,329·81
	Smaller prawns		1,379·84
	Bombay duck		1,418·86
	Carangids		2,047·55
	Perches:		
	Miscellaneous	19·05	
	Goat fish	2,291·09	
	Nemipterus	575·62	
			2,795·76
	Lactarius lactarius		209·55
	Catfish		133·80
	Sphyræna sp.		6·35
	Miscellaneous		20,193·58
	Unspecified		12,145·59
			2,76,798·42

C.	Eels	4,555·06
	Rays	991·10
	Skates	1,698·73
	Saw-fish	446·34
	Catfish	743·90
	Miscellaneous	73·49
		8,508·62
	TOTAL LANDED ..	2,90,600·06

Fish catches in general showed a downward trend during the year. In spite of the more voyages total landing was less than in 1957–58. Kalyani I, the Danish trawler, showed greater catch efficiency and proved to be more suitable for these waters. There was an increase in fish types and decrease of sciænids and glass fish which formed the main stay of this fishery.

C. Physiology and Marine Fish Farming

In order to find out whether by reducing the osmotic load on fish the metabolic (O_2 uptake) rate could be lowered and the fish made to last longer in a restricted volume of water as in fish fry transport, and to analyse the factors which restrict the adults of some marine fish but not their fry from penetrating the lagoons and tidal creeks, some experiments were performed on *Plotosus anguillaris*. It was found out that with reference to the former condition, salinity of 12·5‰ reduced the standard metabolic rate and the lethal level of oxygen by nearly 80% over those of fish normally in sea-water. With reference to the latter aspect, the relatively wider range of metabolic adjustment and probably the osmotically unspecialized nature of the fry are indicated as reasons for their ability to enter into highly fluctuating situations. Further work on similar lines but with greater detail was partially completed on *Tilapia mossambica* where fish of all sizes were acclimated to low salinity and 30° C. and their metabolism measured in temperatures ranging from 15–40° C. As an essential adjunct to the work an apparatus was devised for measuring the release or uptake of chloride by the fish over a prolonged period in different media.

Analysis of figures obtained after the fish harvest of 1957–58 showed that the marine fish-ponds yielded a maximum of 220 kg. of fish per hectare during the year. *Chanos* constituted nearly half the total weight of fish

caught. In this first attempt at rearing fish in the experimental ponds since their construction, supplementary feeds for the fish during the last phase of their growth were found essential in order to maintain them in healthy condition. Owing to the poor fertility of the ponds in the initial stages, organic manures in the form of seaweeds and cow-dung compost and also green manure were helpful in enriching the ponds. During the 1958 fry season some of the ponds were stocked with *Chanos* fingerlings. Length measurements at intervals revealed that the fish with an initial length of 80 mm. maintained a steady increase in length in the order of 120 mm. and 300 mm. at the end of the first and third month respectively. Methods to improve the growth rate and the ultimate yield of fish in ponds are being tried.

A survey of the ecological characteristics and the fishery resources of the lagoon around the experimental marine fish-ponds was completed during the year. This furnishes an important basic background while considering the scope for expansion of salt-water fish culture in this area.

IV. Marine Biology

A. Planktological Investigations

(*a*) *At Karwar.*—Diatom blooms were never noticed although there were indications of increase in diatom population during the monsoon. Dinoflagellates were common during September. *Noctiluca* was abundant during August–September. *Sagitta erflata* was generally observed to be common at Karwar and Chendia and this form was replaced by *S. bedotei* at places farther south and this observation confirms the previous year's findings regarding the chætognath distribution in the North Kanara Coast. Copepods were abundant during August–September and cladocerans in September.

(*b*) *At Mangalore.*—Planktological conditions along the Mangalore Coast during this year, while showing many similarities to those of last year, showed also significant differences. The general trend during the two years were diatom bloom in June, copepod maximum during October–January which coincides with the active fishing season, *Noctiluca* bloom in October which was not of such a magnitude as to affect fishery, dinophysid maximum in September–October, progressive increase of fish eggs and larvæ in the plankton from October–February, maximum of prawn eggs and larvæ during September and October which coincides with the active inshore prawn fishery, maximum of chætognath eggs during December–January, and summer bloom of *Hemidiscus* sp., and swarming of *Lucifer* sp. after March.

The significant differences were: the monsoon bloom of diatoms was of a shorter duration and lesser magnitude. The post-monsoon bloom of diatoms which occurred in January last year was absent this year. The post-monsoon dinophysid bloom was exceptionally good and exclusive swarms of *Ceratium* sp. occurred in the inshore waters during this year. An exclusive swarm of *Temora turbinata* occurred in the first week of November and this coincided with the bumper mackerel fishery all along the zone. An almost exclusive radiolarian swarm occurred in December. The bearing of these facts on the fishery condition in this zone is under active investigation.

(*c*) *At Kozhikode.*—The seasonal cycle of the plankton was more or less of the same pattern as in the previous year. Phytoplankton was at its maximum during the south-west monsoon attaining the peak in July–August, and the usual secondary bloom was conspicuous by its absence. Zooplankton formed the bulk during the north-east monsoon season. The standing crop was generally poor when compared to the corresponding periods last year. The poorest months for the plankton were December and January. Spectrophotometric studies on the chlorophyll content was made while an assessment of the biomass is under investigation. *Fragilaria oceanica* occurred occasionally during the south-west monsoon as usual, but never in abundance at any time. This year its bloom was not a sustained one and this has been partly reflected in the poor oil-sardine fishery during the season. During the monsoon *Hornellia marina* also was seen in good quantities, for a short period but never in abundance as to discolour the water. Minor blooms of *Trichodesmium* spp. were seen during the hottest months. Data on the fluctuations in the magnitude of standing crop of phytoplankton in terms of Harvey Units and production of carbon per unit area were collected. Values up to 12·83 gm. of carbon per metre square of sea-surface for the area were obtained, indicating a high productive potential of the waters.

The pattern of abundance of zooplankton showed but slight variations this year. The copepods were abundant till the outbreak of the monsoon in late June and thereafter revived by August–September and continued, without appreciable dwindling, for the rest. Though swarms of *Evadne* and *Penilia* appeared in September–November they had not their usual abundance. They, however, were present throughout the year, though often scarce. The chætognaths, usually dominant in post-monsoon months, were moderate this year. Medusæ came in large numbers from November–March, mainly *Obelia* and *Aequrea* in the earlier part and *Liriope* and *Nausithœ* later. Swarms of polychæte larvæ occurred in July; they were

erratic for the rest. Penæid eggs and larvæ were abundant, particularly in December, while sergestid and crab larvæ were numerous in February–March. *Noctiluca* swarms appeared in July–August, salps in February–March and appendicularians and pteropods were numerous in December–March. The main period of availability of fish eggs and larvæ were October–December, though appreciable number of carangid eggs were collected in mid-July.

(*d*) *At Mandapam.*—Investigations on the organic production in the seas around Mandapam were continued. In order to check the values of organic production computed from the "dark and clear bottle" experiments, concurrent experiments were carried out using ^{14}C. The collection of data has been extended to five other stations covering a distance of about 20 miles. The changes of total nitrogen and particulate and dissolved phosphorus are being studied.

The study of the characteristics of plankton at various centres in the Gulf of Mannar and Palk Bay revealed the following interesting features during the year: (i) Swarms of *Noctiluca*, which used to occur in the Gulf of Mannar and Palk Bay particularly during the summer months, were completely absent during the year under report. (ii) As in the previous two years *Evadne tergestina* appeared rather late this year also. They occurred during the end of January in the Gulf of Mannar only. (iii) *E. tergestina* was soon followed by a small population of *Penilia avirostris*. (iv) During the end of March there was a sudden appearance of large numbers of *Creseis acicula* in Palk Bay. (v) The standing crop of plankton in Palk Bay during the period January–March was comparatively lower than that of the Gulf of Mannar. (vi) The following blooms were recorded during the year: *Rhizosolenia* spp. and *Chætoceros* spp. in Palk Bay during September, and *Asterionella japonica* during February; *Chætoceros* spp., *Rhizosolenia styliformis*, *Conscinodiscus gigas*, *Thallasiothrix frauenfeldii*, *Hemidiscus hardmannianus* and *Thalassionema nitzschioides* in the Gulf of Mannar during November–December.

Chætognaths seemed less abundant this year both in the Gulf of Mannar and the Palk Bay. Among the 8 or 9 species occurring in these waters, *Sagitta enflata* were the most abundant and an unusual swarm of the species was noted in the Gulf of Mannar in November 1958. Observations on the biology and fluctuations in populations of the copepod *Acartia erythræa* were made. Attempts to rear the species in the laboratory were not successful. A detailed comparative study of the copepod nauplii of the Gulf of Mannar and the Palk Bay based on the material collected during 1952–55

was also completed. A critical study of the spawning of copepods in this area seems to suggest a relation of their spawning with the phytoplankton cycle.

B. Oceanographic Studies

(*a*) *At Bombay*

April–June.—The temperature of the waters varied between 31·8° C. and 26·5° C. The salinity remained more or less steady at 35·6‰ except for an increase to 36·8‰ in the first week of May. With the onset of the monsoon towards the end of June, the salinity dropped down to 22·0‰. The oxygen content of these waters ranged between 3·66 and 6·90 ml./l. and both the highest and lowest values were obtained in the month of May. The inorganic phosphate varied between 0·37 and 0·83 μg.-at. P/l. The dissolved organic phosphate was high, being nearly 60% of the total phosphorous content.

July–September.—The mean temperature values in this period ranged between 27·5° and 28·8° C. The salinity of the surface waters varied from 24·31 to 30·91‰, while the subsurface waters had higher salinity and the highest value recorded was 34·99‰ at a depth of 20 meters in late September. The mean oxygen content of the waters was between 4·5 and 4·8 ml./l. Inorganic phosphate was high in August and in the middle of September and low for the rest of the period; the concentrations ranged between 0·51 and 1·38 μg.-at. P/l. The integrated mean concentration of inorganic phosphate in the entire column down to 20 meters varied from 0·89 to 0·92 μg.-at. P/l. Unlike in the previous quarter the dissolved organic phosphorus was only 15% of the total phosphorous content. The chlorophyll '*a*' values were rather low in early August and early September and increased in the rest of the period. The highest value of 3·32 mg./m.^{3} was in late September.

October–December.—Temperature varied from 26·0 to 30·0° C. and 26·0–28·4° C. in the inshore and off-shore waters respectively. The drop in the temperature was fairly sudden in late November and the discontinuity layer was seen at 25 m. early in November and by the end of the month it had crept up to 13 m. By December the temperature became practically uniform throughout the entire water column. Salinity which had shown an increase to 34·99‰ towards the end of September rose further to 35·35‰ by the end of October and 36·27‰ by the last week of November followed by a decrease to 35·62‰ in December. The salinity distribution at subsurface levels followed the same pattern as the distribution of temperature. The oxygen content was low in October and in early

November and showed an increase in late November, the values being 2·9 ml./l. and 5·2 ml./l. in the respective periods. In December, the values have come down to 4·35–4·10 ml./l. During the October–November stratification in the water column an oxygen-minimum layer was seen to be present more or less at the discontinuity layer which disappeared completely by December when turbulent conditions had set in. The inorganic phosphates in the surface waters varied between 0·40 and 1·36 μg.-at. P/l. The values were low in October and November and high in December. In the entire water column the values were 0·63 μg.-at. P/l. in October, 0·89 μg.-at. P/l. in November and 1·12 μg.-at. P/l. in December. The mean chlorophyll content decreased from 4·36 mg./m.^{3} in October to 1·18 mg./m.^{3} in December. Maximum variations within the same month were seen in October while the minimum was in December.

January–March.—The turbulent conditions commenced in December and continued till the end of February. The water temperature showed a further decrease to 24·2° C., while the salinity remained more or less steady, except for slight fall in late January, the range being 35·71–35·28‰. There was no appreciable difference between the surface and subsurface salinity. Little change in salinity was observed in the succeeding months. The oxygen content of waters also remained steady at 4·3±0·1 ml./l. The inorganic phosphate showed a slight decrease from 0·79 μg.-at. P/l. in January to 0·69 μg.-at. P/l. in February. The integrated mean concentration of phosphates in the entire water column from surface down to 20 metres increased from 0·74 μg.-at. P/l. in early January to 1·09 μg.-at. P/l. towards the end of the month and this was followed by a sudden decrease to 0·67 μg.-at. P/l. in February. Dissolved organic phosphorus amounted to nearly 15–20% of the total. The chlorophyll content showed a slight increase over the December value of 1·18 mg./m.^{3}, the value in January being 1·54 mg./m.^{3} and that in February being 1·72 mg./m.^{3}

(*b*) *At Karwar*

At Karwar, the water temperature, pH and salinity declined during monsoon. Dissolved oxygen content increased. Phosphates remained low throughout but nitrites increased during June–July and silicates were high during monsoon.

(*c*) *At Mangalore*

The year under review showed similar hydrological conditions off Mangalore as those of last year. The influx of freshwaters into the sea during the monsoon period lowered the salinity to a great extent. During the post-monsoon months the salinity as well as temperature gradually increased.

The temperature fluctuated between 27·5° C. and 29·5° C. during the post-monsoon months (October–January).

(*d*) *At Kozhikode*

Studies on the seasonal variations in the hydrological conditions of the inshore and off-shore waters of the Calicut coast were continued. However, off-shore collections were totally interrupted from July–August due to bad weather. In general, the temperature of the inshore waters was higher in April, May and September than that of off-shore waters, and lower in October, November and February. Surface salinity of the inshore waters was higher than of off-shore waters in April, May and October and lower during the rest of the period. Except in April, the bottom salinity of the inshore waters was lower than that of off-shore waters. The surface phosphates and nitrites of the inshore waters were generally higher than those of off-shore waters and in the case of bottom waters it was *vice versa*. Silicate content of the inshore waters was also higher than of off-shore waters. Except in March, the total phosphorus content of the inshore surface waters was higher than that of off-shore and in the case of bottom waters it was lower in the inshore area in May and December and higher during the rest of the period than in the off-shore area. pH of the inshore and off-shore waters remained more or less the same. Surface oxygen of the inshore region was higher than that of off-shore area in September, December and January and lower during the rest of the period. Bottom oxygen of the off-shore waters were generally higher than that of inshore waters.

(*e*) *At Cochin*

Preliminary analysis of the data on physical oceanography collected so far has been completed and the results may be summarised as follows:

Oceanographic conditions after south-west monsoon between Cape Comorin and Cochin: (*a*) There is a south to south-easterly flow along the coast up to 30 m. depth. (*b*) Eddy circulations are prominent between Alleppey and Quilon. (*c*) The divergence at lower levels accompanied by upwelling and tendency towards convergence and steady flow at the surface layers afford a clue towards understanding the dynamics of the formation of mud banks between Cochin and Quilon. (*d*) From 75–100 m. there is a steady countercurrent flowing either north or north-westwards. (*e*) In a layer at a mean depth of 50 m. the flow is indicated to be eastwards. Probably any exchange of water between the Arabian Sea and the Bay of Bengal takes place in deeper layers only. (*f*) The circulation derived from the distribution of salinity is somewhat different from the one derived either

from temperature or density and, as such, there appears to be no direct correlation between temperature and salinity. (*g*) The distribution of temperature should be taken into consideration while deriving the circulation along the west coast of India as the temperature seems to be a more conservative property. (*h*) The last two inferences are in contrast with the conditions in the Bay of Bengal where there is a direct relationship between temperature and salinity.

Summer conditions are as follows: (*a*) The temperature of the surface layer has increased and the surface temperature is generally 31° C. (*b*) The thermocline forms at about 80 m. depth. (*c*) At 500 m. depth, no appreciable change in temperature is noticed as compared to the observation of the previous season. (*d*) Though the conditions are unsettled in the mixed layer, good stability is found in the thermocline region. (*e*) The space variation of salinity is from 33·5–35·5‰. (*f*) Consequent on the rise in temperature the density of surface layers has undergone reduction and the density layers corresponding to $\sigma_t = 25$ now occur at 140 m. whereas it was 80 m. during September–October. (*g*) Lighter waters are present along the coast-line, indicating a northerly current.

C. Algology

During the year under review satisfactory progress had been maintained on the studies of ecology of marine algæ in the intertidal zone in Palk Bay and Gulf of Mannar. It was observed that seasonal cyclic changes in the floral pattern was more constant in Palk Bay than in the Gulf of Mannar. Further, towards a survey of the harvestable grounds of economic seaweeds, a beginning has been made in the Gulf of Mannar area. In this preliminary survey covering the zone from Dhanushkodi to Hare Island it has been observed that Turbinarias and Sargassums are most abundant and more uniformly represented in all the stations than the red algæ. A detailed study of the genus *Hypnea* has been undertaken on account of the wide range in morphological variations within the genus and lack of earlier work on these from Indian waters. It was also possible to make some studies on the distribution of algæ in the Pearl beds off Tuticorin based on samples collected from the Paars. Besides being able to make observations on the colonization of the substratum and growth of the algæ, a number of interesting species also have been recorded on which studies are being made.

Agar prepared from *Gelidium micropterum* has been found to be highly suitable for mycological work in laboratories.

V. Chemistry and Bacteriology of Fish; Fish Curing and By-products

The report covers the period from April up to December 8, 1958, after which date this work, together with the related staff, was transferred to the Central Fisheries Technological Station at Ernakulam. During this period, several objective tests for assessing the quality of preserved prawns in ice were conducted. In the case of one batch of prawns (mainly *Peræus indicus*), preserved in ice, it was observed that leaching in contact with melting ice affected all the water-soluble compounds in the muscle. After 11 days of storage the prawns lost by leaching 40·38% of the total proteins, 63·32% of the water-soluble proteins, 88·73% of the soluble non-protein compounds and 88·16% of the free L-amino-acids. Such information is important from the commercial point of view because it indicates that the storage of fish in ice before processing (which is necessary in most cases) should be reduced to the shortest possible period so that maximum nutrients are retained. This also explains why some of the more common chemical tests for spoilage, such as for trimethylamine and volatile basic nitrogen, do not give any reliable information in the case of ice-stored fish.

Experimental studies on the possible use of shellac as a fish preservative gave encouraging results only in the case of very small fish such as *choodai* (*Sardinella* spp.). Analyses of *Scomberomorus* samples treated with alginate jelly and kept at 14° F. for three months showed that apart from the better physical appearance of the flesh, the development of rancidity was considerably less in the coated sample than in the control. The percentage of salt-soluble nitrogen on the total nitrogen was 34·8 in the coated sample and 31·5 in the control as against 36·1 in the beginning of the experiment, indicating thereby that denaturation of the muscle protein is retarded to a great extent in the treated samples. In the study of the bacteriological and biochemical changes taking place in the fermentation method a series of experiments was conducted with shark flesh. The effect of increasing the fermentation period on the rate of multiplication of lactic acid bacteria was studied. The 4-hour and 8-hour counts were approximately 6 and 8 times the count at 0 hours showing their increased growth during fermentation. Along with this the effect of adding small quantities of free sugars to the fermenting mass in the form of dextrose was studied. Although the rate of multiplication of lactic bacteria was enhanced several-fold, the final product was found to assume a brownish appearance. There was no significant change in the amount of urea removed from the shark flesh as a result of addition of sugar.

Analysis was made of the data obtained in the experiments to study the different aspects of mackerel curing, *viz.*, (i) effect of different methods of dressing the fish prior to salting, (ii) washing the gutted fish in different solutions prior to salting, (iii) optimum salt proportions required, (iv) influence of various chemical preservatives on the keeping quality of the finished product, (v) optimum humidity conditions for storing and (vi) maximum permissible delay between catching and actual processing.

With a view to studying the changes occurring in the fat of *Hemirhamphus* owing to hydrolysis and oxidation while processing, different types of cured products, such as dry-cured, wet-cured and tamarind-cured, were prepared. In all these series separate lots were also prepared after pretreatment with preservative to improve the shelf-life. Experiments were also conducted to study the beneficial effects of treating cured products with prescribed quantity of propionic acid to prevent attack by red halophiles and fungi. Preliminary studies on the digestibility of dry-cured *Lactarius* by enzymatic hydrolysis with pepsin and trypsin were attempted.

Sardine oil sample prepared during the last season was periodically examined for any change in quality during storage. There was little change in the iodine value, acid or free fatty acid content during its storage in the past one year, while in the commercial samples the acid value and the free fatty acids had increased. Possibilities of preparing enzymes from the pyloric cæca of mackerel were also explored.

CENTRAL MARINE FISHERIES
RESEARCH STATION,
Marine Fisheries P.O., S. India,
June 1, 1959.

(Sd.) S. JONES,
Chief Research Officer.

VI. LIST OF PUBLICATIONS DURING 1957–58

168. JONES, S. Authorship of names of Indian fishes proposed in 'Histoire Naturalle des Poissons' by Cuvier and Velenciennes and recorded by Day. *J. Zool. Soc. India,* **9** (2), 121–26.

169. PRASAD, R. R. AND TAMPI, P. R. S. Notes on some decapod larvæ. *Ibid.* **9** (1), 22–39.

170. SEKHARAN, K. V. On the South Kanara coastal fishery for mackerel, *Rastrelliger canagurta* (Cuvier), together with notes on the biology of the fish. *Indian J. Fish.*, **5** (1), 1–131.

171. Gopalan Nayar, S. A preliminary account of the fisheries of Vizhingam. *Indian J. Fish.*, **5** (1), 32–55.

172. Tampi, P. R. S. On the food of *Chanos chanos* (Forskal). *Ibid.*, **5** (1), 107–17.

173. Jones, S. and V. R. Pantulu. On some larval and juvenile fishes from the Bengal and Orissa coasts. *Ibid.*, **5** (1), 118–43.

174. Velankar, N. K. and P. V. Kamasastri. Experimental preservation of fish in Aureomycin Ice. *Ibid.*, **5** (1), 151–59.

175. Suryanarayana Rao, S. V.. *et al.* Preliminary investigations on the pit curing of fish in India. *Ibid.*, **5** (1), 160–69.

176. Prasad, R. R. Plankton calendars of the inshore waters of Mandapam with a note on the productivity of the area. *Ibid.*, **5** (1), 170–88.

177. Jones, S. Notes on the frigate mackerels, *Auxis thazard* (Lacepede) and *A. tapeinosoma* Bleeker, from Indian waters. *Ibid.*, **5** (1), 189–94.

178. Banerji, S. K. and Satyanarayana, A. V. V. A note on the general trend of marine fish catches in India. *Ibid.*, **5** (1), 195–200.

179. Suryanarayana Rao, S. V., *et al.* Studies on the preservation of fish by pickling. *Ibid.*, **5** (2), 326–40.

180. Ramasastry, A. A. An estimation of heat changes in the Bay of Bengal off Visakhapatnam. *Ibid.*, **5** (2), 341–47.

181. George, K. C. On the occurrence of *Anchoviella baganensis* (Hardenberg) and *A. bataviensis* (Hardenberg) along the south-east and south-west coasts of India. *Ibid.*, **5** (2), 348–56.

182. Jones, S. Notes on eggs, larvæ and juveniles of fishes from Indian waters. I. *Xiphias gladius* Linnaeus. *Ibid.*, **5** (2), 357–61.

183. George, M. J. Observations on the plankton of the Cochin backwaters. *Ibid.*, **5** (2), 375–401.

184. Radhakrishnan, N. Observations on mackerel fishery at Karwar for the seasons 1954–55 and 1955–56. *Ibid.*, **5** (2), 258–69.

185. Krishnamoorthy, B. Observations on the spawning season and the fisheries of the spotted seer, *Scomberomorus guttatus* (Bloch and Schneider). *Ibid.*, **5** (2), 270–81.

186. Jones, S. The tuna live-bait fishery of Minicoy Island. *Ibid.*, **5** (2), 300–07.

187. Velankar, N. K. and Govindan, T. K. A preliminary study of the distribution of non-protein nitrogen in some marine fishes and invertebrates. *Proc. Indian Acad. Sci.*, **47 B** (4), 203–09.

188. Prasad, R. R. A note on the occurrence and feeding habits of *Noctiluca* and their effects on the plankton community and fisheries. *Ibid.*, **47B** (6), 331–37.

189. Seshappa, G. Occurrence of growth checks in the scales of the Indian Mackerel, *Rastrelliger canagurta* (Cuvier). *Curr. Sci.*, **27,** 262–263.

190. Prasad, R. R., *et al.* A note on the organic production in the inshore waters of the Gulf of Mannar. *Ibid.*, **27,** 302–03.

191. Velankar, N. K. and Govindan, T. K. The free amino nitrogen content as an index of quality of ice-stored prawn. *Ibid.*, **27,** 451–52.

192. Jones, S. Progress of marine fisheries research. *Fisheries of the West Coast of India*, pp. 8–17.

193. Prasad, R. R. The Arabian Sea—Marine Biology of the West Coast. *Ibid.*, pp. 23–30.

194. Velappan Nair, R. The Sardines. *Ibid.*, pp. 31–35.

195. Pradhan, L. B. and Virabhadra Rao, K. The Mackerel. *Ibid.*, pp. 38–44.

196. Krishna Menon, M. Prawn Fisheries. *Ibid.*, pp. 45–50.

197. George, P. C. Sole Fisheries of the West Coast. *Ibid.*, pp. 51–54.

198. Seshappa, G. Off-shore Fisheries. *Ibid.*, pp. 60–67.

199. Banerji, S. K. Fishery Survey and Statistics. *Ibid.*, pp. 68–73.

200. Thivy, F. Economic Seaweeds. *Ibid.*, pp. 74–80.

201. Tampi, P. R. S. Marine Fish Farming. *Ibid.*, pp. 81–86.

202. Velankar, N. K. Fish Preservation. *Ibid.*, 87–93.

203. Krishna Pillai, V. and Kamasastri, P. V. Fish curing and fishery by-products. *Ibid.*, pp. 94–100.

204. Balan, V. Note on a visit to certain islands of the Laccadive Archipelago with special reference to fisheries. *J. Bombay Nat. Hist. Soc.*, **55** (2).

205. Tampi, P. R. S. On the pelagic swarming of *Polyopthalmus pictus* (Family Opheliidæ—Polychæta). *Ibid.*, **55** (2).

206. Subrahmanyan, R. Ecological studies on the phytoplankton of the West Coast of India. *Memo. No.* 1 *of the Indian bot. Soc.*, pp. 145–51.

207. ———. Phytoplankton organisms of the West Coast of India. *J. Indian bot. Soc.*, **37** (4), 435–41.

208. Antonyraja, B. T. and Prabhu, M. S. An instance of hermaphroditism in the Indian Mackerel, *Rastrelliger canagurta* (Cuvier). *Curr. Sci.* **28** (2), 73.

ANNUAL REPORT OF THE CENTRAL INLAND FISHERIES RESEARCH STATION, BARRACKPORE, FOR THE YEAR 1958-59

General

There was an all-round intensification of the research programmes of the Central Inland Fisheries Research Station during the year 1958–59 and the various research units were strengthened by more research staff and equipment. The Krishna-Godavary Fisheries Research Unit established during the Second Five-Year Plan was shifted to Rajahmundry.

Dr. V. Gopalakrishnan took over as Assistant Research Officer (Pathology) and Shri J. C. Malhotra as Assistant Research Officer (Estuarine).

Training

The 11th Session of the Inland Fisheries Training Course was conducted during the year. 39 trainees consisting of 13 Government deputees from the States of Madhya Pradesh, Orissa and Mysore, 5 Government stipendiaries from the States of Orissa, West Bengal and Assam, 15 private candidates from the States of West Bengal, Kerala, Punjab, Bihar and Mysore and 6 foreign trainees—2 from Malaya, 2 from Thailand, 1 from Burma and 1 from Uganda—were trained in Inland Fisheries Development and Administration. In the final examination conducted in January 1958, 7 candidates were placed in the First Class, 23 in the Second Class and 10 in the Third Class. This includes one candidate from the 10th Session who appeared for examination during the year.

Mr. T. Lashin, F.A.O. Fellow, was given facilities at this Research Station to acquaint himself with the system of collection of fisheries statistics.

Three batches of trainees, numbering 81, from the Directorate of Fisheries, Orissa, were given brief demonstrations on the method of artificial breeding of the common carp, *Cyprinus carpio*, at the Cuttack Sub-Station. Special lectures and demonstrations on fish breeding and fish culture were given at the same station to the Post-Graduate Zoology students of the Delhi University, students of the Andhra Polytechnic, Kakinada, and Agricultural Extension Officers from Assam, North-East Frontier Agency, Tripura and Manipur.

A brief demonstration training on the various aspects of fish breeding by injection of pituitary gland hormone was held at Allahabad for the benefit of Senior Fishery Officers of Uttar Pradesh. Similar demonstration training was given to the District Fishery Officers of the Department of Fisheries, Assam, at the Pond Culture Unit in Joysagar.

A Refresher Course in Fish Culture was conducted for a period of one month at the Pond Culture Sub-Station, which was attended by 10 Senior Officers from State Fisheries Departments, 4 Assistant Fisheries Extension Officers and 1 Fisheries Extension Assistant. The programme of the Course included lectures, demonstrations and field studies in the various aspects of culture fisheries.

A special one week's course of training in methods of induced breeding of Indian carps and breeding of common carp was also held at Cuttack, in which 22 Officers from various States and the extension service participated.

Meetings

Dr. B. S. Bhimachar, Chief Research Officer, attended the Fisheries Research Committee Meeting at Srinagar from 3rd to 6th July 1958 and the State Fisheries Ministers' Conference at Mysore from 14th to 16th July 1958. He also represented the Government of India at the 8th Session of the Indo-Pacific Fisheries Council Meeting at Colombo from 4th to 22nd December 1958.

Equipment

An exploratory fishing and research vessel specially designed for operation in the Sunderbans was received at this Research Station under the T.C.M. Programme during the year under report. The vessel was rigged up for trawling and trial fishing was carried out in the neighbourhood of Kakdwip. A Jeep was also procured.

Visitors

Mr. Tadashi Yammamoto, Deputy Chief of Fisheries Statistics Section, Statistical Research Division, Ministry of Agriculture and Forestry, Tokyo, Japan; Dr. M. R. Khan, Assistant Regional Fisheries Officer, F.A.O.; Shri M. V. Krishnappa, Deputy Minister for Agriculture, in-charge of Fisheries; Shri Krishan Chand, I.C.S., Joint Secretary, Ministry of Food and Agriculture; Dr. N. K. Panikkar, Fisheries Development Adviser; The Hon'ble Mr. G. C. Granado, Minister of Labour, Co-operative Development and Social Services and the Hon'ble Mr. Kamaluddin Mohammed, Minister of Agriculture, Lands and Fisheries of Trinidad; Mr. Talbot, F.A.O./E.T.A.P. Fisheries Officer; Mr. A. K. E. Imam, F.A.O. Fellowship

Holder from Egypt and Mr. Y. Niyake of Fisheries Economic Branch, Fisheries Division, F.A.O., Rome; Shri S. Miskeith, Superintending Engineer; Mr. George Mekenzie, F.A.O., Fishing Fleet Manager, Deep Sea Fishing Station; Mr. K. Chidambaram, Assistant Fisheries Development Adviser; Mr. James Haratani of the University of California; Mr. Noel L. H. Karuss of the Board of Agriculture and Forestry, Honolulu, Hawaii ; Mr. Peter Gurtner, F.A.O. Naval Architect; Dr. S. W. Ling, F.A.O./E.T.A.P. Fish Culture Expert; Dr. K. Kuronuma, Director-Chief, Freshwater Fisheries Research Laboratory, Tokyo and Chairman of the Indo-Pacific Fisheries Council, visited this Research Station during the year.

The Fisheries Education Committee consisting of Dr. N. K. Panikkar (*Chairman*), Dr. B. N. Chopra and Prof. G. M. Gerhardsen (*Members*) visited this Research Station on the 27th and 28th January 1959. The Committee also visited the Pond Culture Sub-Station, Cuttack, on the 29th January 1959.

Pond Culture Division

2. *Induced breeding of Indian carps*

During the earlier part of May 1958, over 100 pituitary glands of maturing major carps were collected from Calcutta fish markets. The glands were preserved in absolute alcohol and used for experiments in Assam. During June 1958, over 600 pituitary glands of mature and maturing major carps, grown in ponds and reservoirs, were collected at Allahabad and Jhansi through the courtesy of the Department of Fisheries, Uttar Pradesh. These glands were also preserved in absolute alcohol and were used for experiments at Cuttack. Over 400 glands from immature as well as maturing major carps were similarly collected during June–July 1958 from the Kila and Chaudwar farms and used for experiments at Cuttack.

Fish breeding experiments were carried out at Joysagar, Assam, from the middle of May till the 1st week of July 1958. Breeders collected from different ponds and kept in stocking ponds were fed with artificial food. At the onset of monsoon, they were netted out from these ponds, segregated sex-wise and released in smaller nursery ponds to facilitate their capture at the time of giving injections. The dose of injection was according to the weight of the fish. The males were given a smaller dose than the females. Intramuscular injections were administered in the caudal peduncular region. The injected fishes, usually a male and a female or two males with one female, were then introduced inside a closed hapa fixed in shallow water. Usually on cool rainy days the fishes spawned within 6–8 hours after the

1st injection. In some cases a second injection after 10–12 hours of the first was necessary. The optimum temperature for breeding was found to be between 24 and 31° C. The eggs were collected when the embryo started twitching movement. The eggs were then transferred to a number of hatching hapas and the fry were stocked in nursery ponds on the 3rd/4th day after spawning.

The experiments were most successful with Rohu. Excepting a few cases when the temperature was high, Rohu spawned as and when injected. Mrigal spawned readily except on two occasions when the females were found to be immature. Several specimens of *Gonius* also spawned. Besides these major carps, Bata, Reba, Sarana, and *Rasbora elanga* also spawned. In the majority of cases the percentage of hatching was quite high especially when the day was cloudy and temperature low. In one instance, almost all eggs of a Mrigal hatched out. It was observed that the percentage of fertilised eggs was higher when a bigger male was put with a smaller female. On certain occasions, the majority of eggs were spoiled, probably due to premature spawning and high temperature.

Little over 10 lakhs of major carp fry were produced at Joysagar by hormone injection and were stocked in nursery ponds, showing thereby that the new technique can profitably be employed for commercial production of quality fish seed at very little expenditure. Due to heavy rains a number of nursery ponds got merged with the stocking ponds and the fingerlings from those ponds could not be harvested. However, more than one lakh of major carp fingerlings could be netted out. This enabled the Fisheries Department, Assam, to cancel their indent for carp fingerlings from Calcutta, for supplies to Joysagar Fish Farm and Upper Assam Area.

A very easy and sure method of identifying the sexes of mature, major and medium-sized carps has been found out. The pectoral fin in mature males during the breeding season has a very rough dorsal surface which in the case of the females is very smooth. This distinguishing character has been observed in all mature males of Catla, Rohu, Mrigal, Calbasu, Gonius, Bata, Reba and Pangusia.

Fish breeding experiments at Cuttack were at first conducted in the cement cisterns. Although in majority of cases the injected fishes bred, in some cases the fertilised eggs started coming to the surface of water, being buoyed up by oxygen bubbles liberated through photosynthesis by the algal crust formed at the bottom of the cisterns. The percentage of hatching was very low. On some occasions the eggs stopped development after few cell division stages. Better results were however obtained by

fixing the breeding hapa in the river. The river-water was much cooler than the pond or cistern water and experiments could be successfully conducted in spite of considerable variations in air temperature. Rohu, Mrigal and Calbasu spawned several times. A single mature female Catla spawned in a cement cistern after 2 injections. The eggs were fully swollen and fertilised but development did not proceed after the initial few stages of cleavage.

Preliminary experiments carried out in cement cisterns and ponds by giving periodic injections of pituitary glands to adults of Rohu, Mrigal and Calbasu during February to June indicated that at least a few of the injected males show positive response. No such response was obtained in females. The experiments are being continued.

A series of experiments on the effect of injections of comparable doses of pituitary glands collected from fishes in various stages of maturity were conducted on *Cirrhina reba* with a view to find out whether glands collected from immature fishes or those in the early stages of maturity would induce spawning when injected. While experiments so far conducted do not warrant any definite conclusions, it appears that pituitary glands of fishes in which the maturation cycle of the gonads has started would induce spawning.

Out of a total of 2,35,000 Rohu fry produced and stocked, the total number of fingerlings recovered so far is over 1,34,000. The average percentage of survival up to the fingerling stage comes to slightly over 57%, the maximum survival being 83·4%. By proper nursery management it has been possible to obtain 1,06,000 Rohu fingerlings by breeding one pair of Rohu. A female Rohu weighing approximately 1·8 kg. laid about 2,98,000 eggs out of which 1,63,000 fry were obtained for stocking. The percentage of survival of fry was 65.

Successful results have been obtained generally by injection of 5–6 mg. dry weight of pituitary gland to a pair of breeders weighing 1·5–2·5 kg. each. In terms of whole glands this means that 1–3 glands obtained from fully ripe fishes, when injected into a pair of breeders of the same species and having more or less similar weight as the donar fishes, usually induces spawning. Sometimes, probably depending upon the state of maturity of the female, even appreciably smaller doses induce spawning. With smaller fishes, proportionately lower doses are required. Very low doses, of the order of 1/10th to 1/4th of an ordinary gland, even when repeated, do not usually induce spawning though the fishes often became excited. It has been observed that breeders injected with lower doses producing negative results

could be released in the pond and then successfully induced to spawn weeks after when higher doses of injections are given. It is also felt that such low dose injections, somewhat early in the season, probably keep these breeders in relatively better maturity condition than in others. This however needs confirmation.

Success has been achieved in stripping carp eggs and artificially fertilising them. Injected males and females are released in the cistern or hapa and the breeders are caught at the right moment when the eggs could be easily stripped out and then fertilised by the milt from the males. Preliminary experiments have given encouraging results. On one occasion more than 90% of the eggs hatched out and about 70% of the fry survived.

With the success of induced breeding of carps, hybridisation among them could be easily attempted and the preliminary experiments carried out have met with immense success. It has been possible to obtain 12 different hybrids by inter-crossing major and medium-sized carps belonging to 3 genera (*Catla*, *Labeo* and *Cirrhina*) and six species. In addition, another hybrid has also been obtained by inter-crossing *Labeo rohita* with *Cyprinus carpio*. Preliminary observations on the growth of some of the hybrids were found to be very satisfactory. Further studies on the subsequent generations (if any) might help in raising new strains of better culturable qualities by selective breeding.

3. *Breeding and Propagation of the Common Carp*, Cyprinus carpio

A consignment of the Chinese strain of the common carp (Scale carp) was brought from Bangkok to Cuttack, in August 1957 for experimental purposes. Intensive work carried out on various aspects of the biology and propagation of the species in Indian waters has yielded very valuable information. The specimens have during the past 18 months attained a maximum weight of 8 lb. (3·6 kg.) and length of 55 cm., the average weight of the breeding females being 2–2·5 kg. (4–5·5 lb.). For males of the same stock average weight is 1–1·5 kg. Specimens from the first breed in India, now just one year old, have attained a maximum weight of over 4 lb. Under identical conditions growth of fingerlings of the common carp is far quicker than that of Mrigal; as good as that of Rohu and slower than of Catla.

Observations so far made confirm the omnivorous feeding habit of the fish. Fry subsist largely on zooplankton, and do not thrive well when algal blooms predominate. Food and feeding habits of young fry are similar to those of the fry of Indian carps. Feeding habits of fingerlings and adults are similar to those of Mrigal and resemble those of Rohu only

to a certain extent. The fish responds to artificial food, better than Catla or Rohu.

Sexual maturity is often attained when the fish is only about 6 months old, males attaining maturity earlier than females. Fecundity was found to increase with size. Ovaries, when fully ripe, weigh 1/5th to $\frac{1}{4}$th of the total weight in smaller specimens and $\frac{1}{8}$th–$\frac{1}{6}$th in larger specimens. Number of mature ova per gm. weight of ovary is approximately 1,000.

The common carp breeds almost throughout the year. A single female specimen can spawn at least 4 times a year, the period required for recoupment and maturity of ova after one spawning being $2\frac{1}{2}$–3 months. Mature males are found in the oozing condition throughout the year and single specimen could be repeatedly used even on succeeding days for spawning. The quantity of milt shed at a spawning ranges from 1/20th to 1/25th of the total weight of the fish. Eggs of the fish are small, 1·3–1·5 mm. in diameter and adhesive. Though natural spawning takes place occasionally, the fry or fingerlings produced thereby are very limited in number.

Fully ripe specimens of the carp can be easily induced to breed in cement cisterns or in cloth hapas. Material for depositing eggs, in the form of aquatic weeds or some vegetable fibres (Kakabans) should be provided for successful breeding. Segregation of sexes for 1 or 2 days and then bringing them together is helpful to induce breeding. As the males are smaller, 2 or 3 males will be required to fertilise the eggs of a large female. Breeding generally takes place within 12–36 hours after putting the specimens together. In a cistern $12' \times 6' \times 3'$ with $2'$–$2\frac{1}{2}'$ of water, one female and two or three males can be successfully used. A female 2·5 kg. in weight, will lay about 3–$3\frac{1}{2}$ lakhs of eggs at one spawning. For successful hatching, the weeds with the attached eggs should be transferred to another cistern. Without running water, 40–50% of the eggs will hatch out within 46–55 hours after fertilisation. Percentage of hatching will be higher if running water is provided. The weeds with eggs can be kept in cloth hapas fixed in water and hatched. Two days after hatching the fry can be stocked in nursery ponds prepared in the same manner as for fry of Indian carps. Survival in nursery ponds during the first 15 days of rearing ranges from 20 to 60%. 12–15 days old fry ($\frac{3}{4}$"–$1\frac{1}{4}$" long) can be successfully transported after conditioning for about 3 hours. 1,000 such fry, in 10 litres of water in a plastic bag, sealed with about 6 litres of oxygen can be transported for a period of 24 hours with mortality not exceeding 3%.

4. *Tilapia investigations*

A set of experiments designed to show the compatibility or otherwise of *Tilapia* in carp ponds have been in progress in 20 ponds at Puri. Experiments so far conducted indicate that *Tilapia* being an aggressive species, quickly establishes itself in the ponds and its population adversely affects the carps in their growth and survival. Of the major carps, Mrigal is the most affected.

An experiment on the role of *Tilapia* on the survival and growth of advanced fry (15 days old) of Rohu and Common carp indicated that the total production of fish in ponds stocked with Rohu and common carp fry is more than that (*a*) in ponds stocked with *Tilapia* alone or with a combination of *Tilapia*, Rohu and common carps, (*b*) the presence of *Tilapia* population appears to have resulted in a fall in the survival of Rohu fry by 17–22% and of common carp by 16%, (*c*) in the case of Rohu as well as common carps the presence of *Tilapia* appears to have caused very poor growth, the average individual weight attained being only about half that in the control ponds and (*d*) in ponds where all the three species were stocked together the presence of Rohu and common carp has adversely affected production by *Tilapia* to the extent of only 36% as compared to the controls, while the presence of *Tilapia* has adversely affected production of common carp to the extent of 61% and that of Rohu to about 64%. In another field experiment with *Tilapia* and common carp it was found that the presence of *Tilapia* lowers survival of common carp by about 18%, though the presence of common carp was not found to adversely affect survival of *Tilapia*. Production of common carp alone is about 60% more than that of *Tilapia* and does not exceed that of the latter stocked alone. When stocked together, the production of each species is lowered by about 38% as compared to ponds where the species are separately cultivated.

Preliminary experiments carried out on the role of *Tilapia* as a forage fish for the murrel, *O. striatus*, indicate that (*a*) adult *Tilapia* (sexes—equal) at the rate of 500 per acre and murrel fingerlings at 650 per acre, are stocked simultaneously in a pond, the latter keeps a complete check on the multiplication of *Tilapia*, (*b*) the survival and growth of murrels are very much better when stocked with *Tilapia*, indicating that the murrels utilize *Tilapia* as forage, (*c*) production of *Tilapia* alone (470 lb./acre) is almost double that of the combined production of murrels (128 lb. acre) and *Tilapia* (114 lb.) when stocked together and (*d*) the production of murrels alone, in the absence of Tilapia as forage is very low (25·5 lb. acre).

The parental care afforded to the young fry ensures a high rate of *Tilapia* survival and results in rapid over population. Growth is consequently retarded and the bulk of the natural population consists of small fish. Keeping down the population in the pond by periodic harvesting of the larger fish appears to meet the requirements to a certain extent. A one acre stocking pond was cleared and stocked with 120 adult *Tilapia* in September 1957. Fish from this pond was thereafter harvested at almost monthly and fortnightly intervals. The size of marketable fish, however, went down but large-scale thinning restored the size to certain extent. During a period of 12 months, a total of 14,805 specimens weighing 1,092·66 lb. were cropped from the pond. More regular and frequent harvesting was attempted thereafter. Approximately 50 lb. of *Tilapia* were removed every week and during the 6 months period from September 1958 to February 1959, a total number of 7,780 fish, weighing 1,129 lb., were harvested. This shows that compared to the first year, the average size of the fish has markedly improved as also the yield from the pond.

5. *Experiments on fish culture in paddy fields*

Experiments on the cultivation of fish in irrigated paddy fields were conducted and two of the exotic fishes in India, *viz.*, *Tilapia* and the common carp, were used. The experiments with *Tilapia* lasted for 3 months from February to May 1958. Fingerlings were stocked at the rate of 1,000 per acre. The fish repeatedly spawned in the fields during the course of the experiments. The total yield in the experimental plots ranged from 55·5 to 87·5 lb. per acre, with the average at 69 lb. Of these, more than half the quantity was made up of miscellaneous fish and *Tilapia* constituted only about 40%.

In the second experiment, fingerlings of common carp were stocked at the rate of 1,000 per acre. The duration of the experiment was 10 weeks during September–December 1958. The results indicated that (*a*) the survival of the stock was extremely low, ranging from 0 to 3% only, (*b*) the major cause of this low survival was predation by otters and birds of prey, (*c*) the average yield of fish from these plots was only 15 lb. per acre, with the maximum at 27·5 lb. and of this, common carp accounted only for a third, and (*d*) during the 10 weeks' period of the experiment the specimens of common carp that survived showed remarkable growth, reaching an average of ¼ lb. from the initial weight of 4 gm. The maximum weight attained by a specimen was 238 gm. The excellent condition of the survived specimens clearly indicated that but for predation, the plots could sustain a much larger number of fish.

The survival of the fry of Indian carps that entered the plots with irriga tion water was also as low as that of common carp. Though all of them were approximately of the same age, the average weight of Catla alone was comparable with that of common carp; that of Rohu and Mrigal being very much lower.

6. *Weed control investigations*

About 40 weed infested ponds and tanks were surveyed in Balasore, Mayurbhanj, Keonjhar and some areas of Cuttack and Dehnkanal, taking into consideration the nature of the weeds in relation to the physico-chemical features of the water, soil and other casual factors. The majority of ponds with shallow water were infested with weeds. Most of the perennial tanks with a depth of over 15′ had practically no submerged vegetation even when the water was clear. Where the pond edge has been kept steep, the marginal fringe of plants was very much reduced. Tanks with bloom of *Microcystis* or constant turbid waters were also free of submerged vegetation.

The most common weeds in the areas surveyed were *Limnanthemum cristatum*, *Nymphea* spp., *Hydrilla naias*, *Vallisneria*, *Ottelia*, *Scirpus articulatus* and *Chara*. Occasionally, however, *Ceratophyllum*, *Utricularia*, *Nelumbium*, *Potamogeton*, *Limnanthemum indicum*, *Ipomea aquatica*, *Jussiæa repens*, *Trapa natans*, *Limnophila*, *Pistia*, *Azolla*, *Narsilea* and *Nitella* occurred in large numbers. Water hyacinth and *Salvinia* were also occasionally met with in shallow waters and swampy areas. Since the submerged weeds, particularly those with an anastomosing system of underground stems, are the most troublesome, more attention was devoted to the submerged weeds during the year under review.

Further experiments were carried out both in cement cisterns and nursery ponds to study the effect of urea on other plants like *Ottelia* and also to find out the exact cause of mortality of fish. *Ottelia* was completely killed and uprooted in concentrations of 50 p.p.m. or more (up to 125 p.p.m. was tried) in two weeks' time, whereas the plant was not affected with 25 p.p.m. There was also development of algal blooms when the concentration was 50 p.p.m. or more. *Tilapia* died in cisterns, treated with 50 p.p.m. or more, most probably due to the production of high concentrations (16–36 p.p.m.) of free ammonia, compared to the maximum of 1 p.p.m. in the control and 3·2 p.p.m. in the cistern treated with 25 p.p.m. In nursery ponds, urea at 50–75 p.p.m. was successfully employed in removing all unwanted fish. Further experiments indicated that it might be possible to kill submerged weeds like *Hydrilla* by two or more applications of the

fertiliser at intervals of 2–3 months or when the bloom disappears thereby maintaining a continuous algal bloom.

Organic fertilisers like mustard oil-cake, fish meal and compost were also tried in cement cisterns to find out whether they have any killing effect on submerged weeds and whether an algal bloom will develop with these fertilisers also. A very high dose of 5,000–10,000 lb. per acre was tried. Both the oil-cake and the fish meal killed the weeds completely within about 3 weeks and in course of time a bloom of algæ developed. The compost did not produce any appreciable effect, probably because the quality was not satisfactory. Because of the very high dose applied there was fouling of water to some extent and a large percentage of the fish in the cisterns died mainly due to oxygen depletion. Further experiments on economic doses of these organic manures are being taken up, both in cement cisterns and in the field.

It has been definitely established that sodium arsenite in concentrations of 4–6 p.p.m. kills most submerged vegetation thoroughly and the effect of one clearance lasts for 4–6 months, the cost of chemical being approximately Rs. 15 per acre foot. Observations carried out on field scale during 1957–58 and continued during 1958–59 have indicated that (*a*) on the wake of decomposition of the submerged weeds, an algal bloom appears always on account of the increased dissolved organic matter, (*b*) the nature of the algal bloom varies with the season and the presence or absence of the concerned algæ at the time of decomposition of the weeds, (*c*) the blue green bloom which usually appears last tends to become permanent, (*d*) when the permanent bloom is established, the submerged vegetation do not appear again, and (*e*) according to present indications the number of treatments of sodium arsenite required to create a permanent algal bloom is two to three.

Preliminary experiments carried out in glass jars indicate that borax at 500–1,000 p.p.m. kill *Hydrilla* in about 2 months. 250 p.p.m. was also found effective, but the time taken was about 3–5 months. 100 p.p.m. of the chemical had no appreciable effect. Plants treated with the higher doses first turned yellow and then into brown. At the end of the experiment it was found that the plants came off in bits, even though they did not actually dissolve in the water.

Field observations were carried out to determine the conditions favouring the growth and multiplication of a few common submerged weeds. In experiments with earthen gumlas and using different types of soil substrata, the best growth of the plant was observed in humus and combinations of humus with other types of soils. There was also a distinct correlation

between the humus content of the substratum and the total alkalinity of the water, the alkalinity being much higher wherever humus was included. Thus it appears that a fairly high amount of organic debris and high total alkalinity of the soil and water respectively encourages profuse growth of plants like *Hydrilla*.

Four tanks at Cuttack containing a large number of *Ottelia* have been kept under observation for a period of over six months. These waters showed a wide range in physico-chemical features. Reproduction in the plant appeared to be almost exclusively by seeds. Under favourable conditions a large percentage of the seeds are capable of germination, which usually takes place at the commencement of the monsoon season, the seedlings being almost indistinguishable from *Vallisneria* at the initial stage. The type of leaves characteristic of *Ottelia* are developed at a later stage. Control of *Ottelia* appears to be possible by the destruction of the plant before it starts producing fruits and seeds.

Year-round observations on the economics of chemical and manual clearance have shown that clearance of submerged weeds by the application of sodium arsenite is much cheaper than continuous manual clearance. A section of the Killa Moat (0·97 acre) required three treatments of sodium arsenite aggregating 103 lb. and another section of 1·33 acres required two applications totalling 108 lb. for completely clearing all submerged weeds and creating a permanent algal bloom in the course of one year. This worked out to Rs. 93·00 of chemical per acre three feet deep, whereas manual deweeding had to be done seven times in similar sections in the course of one year at a total cost of Rs. 265 per acre.

7. *Soil composition and fish production*

With a view to study the soil reaction and the available macro nutrient status of piscicultural soils of Orissa and Bengal and also to determine the water quality of these tanks, a programme was taken up to survey a large number of fishery tanks in Orissa and West Bengal. About 40 fishery tanks covering 10 districts in Orissa and about 30 fishery tanks in three districts of West Bengal have been surveyed so far.

Results obtained showed that many of the piscicultural tanks in the State of Orissa and Bengal are slightly alkaline or slightly acidic. Available soil phosphorus was rather poor in Orissa soil while in tanks studied so far in Bengal, it was comparatively better. In three fish farms in Howrah, available soil phosphorus in water showed a rather high figure and a somewhat direct correlation between available phosphorus of the soil and the soluble phosphorus in water.

To study the growth rate of Catla, Rohu and Mrigal under different soil conditions, the twelve selected tanks in the State of Orissa and six tanks in Madhya Pradesh were stocked with carp fingerlings at a uniform rate. Regular observations on soil and water conditions were continued and growth rate of fish was measured after about one year. The results obtained so far indicate that for these types of slightly acidic or slightly alkaline soils, available soil phosphorus play an important role in determining the fish production. Available soil nitrogen showed irregular fluctuations and does not appear to have any direct correlation either with available phosphorus or with fish production.

With a view to study whether poorly productive acidic soils can respond to corrective treatment by limeing and different combinations of inorganic fertilisers (superphosphate) and organic manure (cow-dung), the experiments taken up in 1957 in 24 nursery tanks at Lingipur were continued this year also. The dosage of chemicals and the method of treatment were the same as in previous year. This type of acid soil did not appear to respond to limeing very easily. It was observed that even a heavy limeing alone was not able to increase the soil pH appreciably nor was it able to increase the soluble alkalinity in water markedly, the increase in dissolved alkalinity being of a temporary nature only. This showed that reserve soil acidity was rather high for these soils. It was noted, however, that lime played an important role in increasing the available soil phosphorus when applied with superphosphate. Thus it was observed that increase in available phosphorus for combination (*a*) high lime *plus* low phosphate and (*b*) high lime *plus* high phosphate, was greater than that for low lime and high phosphate.

In order to study the role of the trace element manganese when applied with inorganic fertiliser superphosphate, an experiment was taken up in six nursery ponds at Chaudwar. Observations made so far indicate that in ponds fertilised with superphosphate alone and in conjunction with trace element manganese, there was a rapid increase in soluble phosphate which diminished gradually, but soluble manganese in water was maintained for a longer period in ponds treated with manganese. After the treatment, it was observed that in tanks treated with superphosphate and manganese, the production of plankton was greater than in both control ponds and in ponds treated with superphosphate alone. Later on, while the zooplankton concentration remained steady in tanks manured with superphosphate alone, there were wide fluctuations both in volume and quality of plankton in other tanks.

Riverine and Lacustrine Division

8. *Fishery investigations in the Ganga River system*

The annual fish landings at the Sadiapur Assembly Centre on the River Jumna were estimated to be 1,40,799 kg. as against 1,93,890 kg. in 1957–58, 4,81,650 kg. in 1956–57 and 3,44,430 kg. in 1955–56. A comparison of the monthly catches in different years shows that landings in the Jumna are higher during the post-monsoon and early winter months, September–January. The poor catches generally are in the monsoon months July and August. There is an obvious progressive decline in the total catches from year to year and it is mainly due to poor landings of *Hilsa* in these years.

It is obvious that there has been a continuance of progressive downward trend in the catches of "endemic" fisheries over the four years. The relevant frequency of occurrence of various size-groups of each fishery, constituting the commercial catches, does not appear to show any significant fluctuations from year to year, which might suggest that decline is mainly due to over-fishing. The other possible factors for the downward trend may be (*a*) extreme draught conditions or excessive and untimely floods, (*b*) switch over of profession of a section of fishermen, (*c*) general economic condition of fishermen and (*d*) silting up of chartered fishing grounds in the basin.

The fishery of *Hilsa* during the year under report was extremely poor and represented only 5·9% of the total annual landings. *Hilsa* was available in all the months excepting June and July, and the size-group 410–520 mm. was the most predominant throughout the year (56·2%). The size-group 255–395 mm. was the next important and these two groups together made up 93·3%. The juveniles (up to 240 mm.) appeared during January–April.

The fishery of major carps accounted for 36·7% of the total annual landings as against 35·1% in the previous year. Among these, Mrigal continued to be the most important (60%) with Catla making up 20·0%, Rohu 12·0% and Calbasu 8·0%. The larger size-groups of all the species were better represented in the catches during the present year than in the previous year. This would perhaps suggest that the gears used during the present year have been somewhat selective. Mrigal fishery was considerable during all the months.

The cat-fish fisheries was the most important during the year, contributing 43·2% of total annual landings. *Mystus* spp. (*aor* and *seenghala*) accounted for over 52% with *Wallago* making up 14·3%. The Scheilbeid fishes, Garua, Vacha and Coilia, made up together 11·8% of the annual cat-fish catches.

Among other fisheries, the miscellaneous group mainly represented by *Aspidoparia*, *Chela*, *Puntius*, *Amblypharyngodon*, *Mystus* (*vittatus*, *cavasius*), clupieds (*Gadusia* spp., *Corica*) was the most important contributing about 11·7% of the total annual landings.

At the Daraganj Assembly Centre on the Ganga, a total of 49,078 kg. of fish was landed during the year as against 54·968 kg. in 1957–58. The low catches during the year have been mainly due to poor landings of *Hilsa*.

The fishery of *Hilsa* was very poor in the Ganga River at Allahabad, being 3,115 kg. and represented only 6·3% of the total landings as compared to 19·8% in the previous year. Insignificant catches were made in most of the months excepting December and January. There was significant improvement in the catches of major carps, most of the cat-fishes and other endemic species.

The species composition of the fisheries of the Ganga (Daraganj) at Allahabad follows similar pattern as observed for the fisheries of Jumna (Sadiapur) with major groups of species represented in comparable proportions from year to year. It is, however, observed that the fishery of Sheilbeid fishes (Garua, Vacha and Coilia) as also that of *S. phasa* and Freshwater Rays are more important in the Ganga.

From an analysis of data collected for 1955–57, it is estimated that the total fish catches, exclusive of tortoises, in a 40-mile stretch of the Ganga and landed at Buxar were 2,44,531 kg. in 1955, 3,18,686 kg. in 1956 and 3,12,410 kg. in 1957. The tortoise catches in these years were 11,489, 7,386 and 7,970 respectively. During the year under report, the major carps were predominant in June and December–February. Among the carps, *C. mrigala* was the most important. Catla and Rohu contributed substantially to the carp catches in the summer months, March–June. Calbasu formed a minor fishery only. The cat-fishes predominated in April, June, July, September, December and February. *Mystus* was the most important in April–July and September and *Wallago* in October–December. *E. vacha* and *C. garua* formed fisheries of considerable importance during December–April, accounting for 11·7–20·7% of the total catches. The Freshwater Rays and Tortoises were caught in considerable numbers at Buxar in almost all the months.

9. *Biological investigations*

A total of over 27,996 kg. of *Mystus aor* and 17,093 kg. of *M. seenghala*, valued together at Rs. 55,950, were estimated to have landed

during the year at the two assembly centres of Allahabad. The fishery of *M. aor* and *M. seenghala* from the Jumna was comparatively more important than that from the Ganga, constituting 70·0% of the total *Mystus* landings. *Mystus aor* was generally represented by larger size-groups. The juveniles (up to 300 mm.), which constituted 9·1%, were available in almost all the months. In *M. seenghala*, while almost all the size-groups were adequately represented, the size-group 480–560 mm. was the more dominant with larger groups coming next. Juveniles constituted 12·8%.

Over 1,050 specimens of *M. aor* at Sadiapur and Daraganj centres were examined during the year. The sex ratio has been calculated to be 37·2 M.: 62·8 F. at Sadiapur and 44·8 M.: 55·2 F. at Daraganj. In *M. seenghala* the sex ratio was found to be 39·0 M.: 61·0 F. for Sadiapur and 44·2 M.: 55·8 F. for Daraganj. The females of both the species were available in comparatively larger numbers in almost all the months. The development of gonads towards maturity presumably commences early in December as reflected by fairly mature specimens encountered in January and February. The breeding commences in March and continues up to August. The fecundity of *M. aor* was determined to be between 45,410 and 1,18,183 in the size range of 856–984 mm. (range in ovary weight being 43·8–151·0 gm.). The fecundity of *M. seenghala* was found to be 65,660–1,066,64 in the size range of 938–45 mm. with range in ovary weight 53·6–107·2 gm.

The adults of *M. aor* subsist on teleosts (50·53%), insects (19·57%), crustaceans (4·86%) and plant debris (3·27%). The adult *M. seenghala* on the other hand subsists mainly on teleosts (85·34%) and only very small percentage of insects and crustaceans. The teleost diet is mainly made up by *Puntius*, *A. coila*, *R. cotio*, *A. morar*, *Mastacembalus* sp., *E. vacha*, *Chela* spp., *G. giuris* and insect diet of beetle larvæ, nymphs of May fly, Dragon fly and larvæ of *Eristalis*, *Dixia* and *Pedicia*.

While Peterson's method is primarily utilised for age and growth studies, the otoliths, vertebræ, spines and cleithrum bone are also examined to determine the validity of the markings for age determination.

The coefficient of condition K in respect of 499 specimens of females in 1954, 276 in 1955, 217 males in 1954 and 179 males in 1955 have been calculated separately with a view to study the ponderal index of *E. vacha* month-wise and season-wise. For females the values of coefficient condition K ranged between 0·524 and 0·854 in the size range of 121–385 mm. in total length in 1954 and between 0·438 and 0·952 in the size range of 148–361 mm. in total length. For males the values of K ranged between 0·451 and 0·918 in the size range 145–280 mm. in 1955.

An analysis of length-frequency data for *Chela gora* showed that the fish attains a total length of about 110 mm. in the first $1\frac{1}{2}$ years, 170 mm. at the end of $2\frac{1}{2}$ years and 215 mm. at the end of $3\frac{1}{2}$ years. The largest specimen recorded from Allahabad was 230 mm. in total length. The monthly growth in the first $1\frac{1}{2}$ years of its age has been calculated to be 6·0 mm.; 5 mm. between $1\frac{1}{2}$ years and $2\frac{1}{2}$ years and 3·75 mm. between $2\frac{1}{2}$ years and $3\frac{1}{2}$ years. The mature specimens were encountered during the period January–June and spent fish in June and July. The occurrence of hatchlings, larvæ and fry of *C. gora* in large numbers during the period February–July suggests that the fish breeds during these months. The fecundity of one specimen (T.L. 207 mm.) with ovary weight 5·70 gm. was 36,263. The stomach contents of 82 specimens have been analysed and it was seen that the fish subsists mostly on teleosts (54·6%). The insects made up 37·7% and crustaceans 5·0% of the diet.

The total length-frequency data of the four major carps landed at Sadiapur, have been analysed for the years 1954–57.

The size attained by *C. mrigala* at various ages has been estimated to be as follows:

1st year—340·5 mm.; 2nd year—540·5 mm.; 4th year—780·5; 6th year—860·5 mm.

The average monthly growth rate works out as:

Up to 1st year	..	28 mm.
Between 1st and 2nd year	..	17 mm.
Between 2nd and 4th year	..	10 mm.
Between 4th and 6th year	..	5 mm.

The mean length and standard error of monthly samples of *C. mrigala* landed at Sadiapur have been calculated for the period 1954–57.

Four centres, two in Jumna (A and B), one in Ganga (C) above the confluence of the two rivers and one below the confluence (D) were selected for the study of physico-chemical conditions. Ganga water at centre C was slightly turbid throughout. Dissolved oxygen, alkalinity and chloride content in the river Jumna are richer than the Ganga, but as regards phosphates, Ganga (C) showed a tendency for maintaining higher values. Nitrates and silicates did not, however, show any sharp differences between the two rivers.

The period of optimum plankton production is from April–July and the period of decreased production is August–October and January–February. Highest number of phytoplankton was noted in May, while the zooplankton showed maximum number at centre C during April.

Material for studies on age/size class composition, maturity and feeding of fish stocks was made available from departmental fishing for six months. The results indicated that clupeids are represented by four species, *Hilsa ilisha*, *S. phasa*, *G. chapra* and *G. manminna*. The fishery of *S. phasa* was the most dominant in the clupeid catches. During April–June the dominant size-group was found to be 181–90 mm. and in August 231–40 mm. Examination of 280 guts of this species show that the fish subsists mainly on teleosts, dipteran larvæ and prawns. The fecundity of the fish of size range 160–282 mm. was found to be 4,018–28,020. *G. Chapra* also formed an important fishery with the size-group 116–20 mm. dominant in April, 116–20 mm. in May and September. The fish subsists on organic matter, *Cladocera*, crustacea, insects, rotifers and diatoms. *G. manminna* was found to be the least important of the clupeids and were available in the catches in June and July only. The dominant size-group was 81–85 mm. in June and 91–95 mm. in July.

Ten species of cat-fishes were available in the departmental catches, but the bulk was made up by the Scheilbeid fishes *E. vacha*, *C. garua* and *A. coila*. Carps were mainly represented by *Chela* spp., *A. morar* and *Puntius* spp.

Spawning of major carps and minor carps was found to be in the months July–September in the Ganga River and extended up to third week of October in Jumna River. Early fry of *Mugil cascasia*, *Liza corsula* and *S. phasa* were available in the two rivers in April and May with *Oxygaster* (*Chela* spp.) appearing in May. From June to September the catches showed early fry and advanced fry of these species along with those of major and minor carps and a few cat-fishes like *Rita rita*, *Silonia silondia* and *Pangasius pangasius*. The carp fry were available in the Jumna only upto third week of October, and fry of two *Mugil* species, *S. phasa*, *A. morar* and *Puntius* dominated in the two rivers during September–November.

A preliminary survey of the fisheries resources of Bramhaputra River system in Assam was undertaken in February–March. The six districts of Lakhimpur, Darrang, Sibsagar, Nowgong, Gauhati and Goalpara were surveyed. It was found that the resources of Bramhaputra are being exploited at a level where it appears necessary to implement some conservancy measures to control the present exploitation and improve the status of various fisheries.

Over 135 species of fish have been collected from the drainage including the hill stream, the lower reaches of Bramhaputra and its tributaties. The system of leasing out the Government waters is extremely defective and has resulted in excessive exploitation of all the waters in the State. The co-operative movement is still in its infancy and the fishermen have organised themselves into a co-operative society merely to avail of some benefits. It is interesting to note that the important office-bearers of these co-operative societies in most of the cases are not actual fishermen. The prime need of the fishing community of Assam appears to be a proper organisation of co-operative society of *bonafide* fishermen.

10. *The Ganga survey*

The total fish production for the year in the River Ganga has been estimated to be 7,11,383 kg. Lowest catches were recorded in August (1·6%) and highest in December (13·7%). The heavier landings were observed during October–March when over 67·2% of the annual catches were landed. The annual fish production from the Jumna has been computed to be 5,27,954 kg. and over 70% of the catches were landed during November–March. The lowest catches were recorded in August (2·3%) and highest in December (17·0%). The species composition of catches from the two rivers showed that the major carps constituted over 47·1% from the Jumna as against 29·3% from the Ganga, but the fishery of *C. mrigala* was the most important in the two rivers. The cat-fishes contributed over 36·3% in the Ganga as against 46·1% in the Jumna. *Hilsa* contributed substantially to the catches from the Ganga (15·4%) but it formed only negligent fishery in the Jumna (1·6%).

Over 59,154 kg. of *Catla*, constituting 8·3% of the total annual landings, have been estimated to have landed from the Ganga River between Fatehgarh and Rajmahal. The heaviest landings were recorded in December and January and lowest in August. The size-group 66–86·4 cm. was predominant during April–July and juveniles (up to 30·0 cm.) in August–November. The fish subsisted mainly on Diatoms (*Synedra* and *Pediastrum*) and *Spirogyra*. The gastrosomatic index ranged between 0·01 and 0·06.

The coefficient of condition K was determined month-wise for the fishes from Agra locality (Jumna) and the values were highest in June and July, which probably suggests a breeding season from late July or early August. The sex ratio for the year was found to be 10 M.: 9 F.

21,599 kg. and 5,720 kg. of *Silonia silondia* were landed from the Ganga and the Jumna respectively during the year. The heaviest catches were recorded in December and lowest in August. The fish subsists on teleosts

(*Mugil* sp., *S. phasa*, *Puntius*, etc.), and insects (larvæ of Diptera, Coleoptera, *Chironomus*, water bugs and nymphs of Odonata). The breeding season of *Silonia* is perhaps protracted, during April–September. The peak breeding period, as reflected by high values of gonado-somatic index in July (1·12) however is August–September. Fecundity of one specimen (1,220 mm. in total length) with ovary weight 220·36 gm. was calculated to be 4,26,783. The sex ratio for the year is 2 M.: 3. F. The general length/weight relationship is expressed as $W = 0{\cdot}0003158 < 2{\cdot}7578$.

11. *Water pollution studies in the River Ganga at Kanpur*

The problem of pollution at Kanpur arises out of about 60 major industrial undertakings—tanneries, textile, and woollen mills and the domestic sewage of the city, the wastes from which are discharged into the river system. Regular observations, as to physico-chemical conditions, plankton biota and fish fauna, were made at eight sampling stations in a 21-mile stretch of the river. The pollutional wastes tend to affect the quality of water by depressing the dissolved oxygen and pH values and by increasing the B.O.D. and Oxygen consumption capacity, Ammonia, Albuminoid ammonia, etc. The near septic conditions were noticed at station II (close to the Bridge) during June 1958 with lowest D.O. and high B.O.D. values. In September and December the conditions had improved to near normal conditions, but by January and February, the mild pollutional conditions had reappeared. At station V near the main sewage outfall, discharging over 20 million gallons of combined effluent and sewage, the pollution was very apparent in January and February with low D.O. and high B.O.D. values.

Septate and non-septate fungi, *Nebelia* and other protozoans occurred below sewage outfalls. *Difflugia* was predominant in natural unpolluted water. Among plankton organisms Rotifers were the most abundant group and various genera showed different responses to the changed conditions of the water. Copepods and cladocera had a tendency to avoid the pollution zones where they occurred in decidedly lower numbers. Myxophycea were abundant in polluted stretches and Chlorophycea in recovery zones. Over 90 planktonic forms have been identified and their distribution in different zones studied.

The apparent toxicity limits of six compounds, found in the tanneries and textile wastes, have been determined with *C. mrigala* and *P. sophore* as test animals.

The bioassay experiments have shown that the process waters do not exert a high degree of toxicity to fish life on account of great dilutions in the river.

12. *Narbada-Tapti survey*

The two fishing centres Hoshangabad and Shahganj handle the catches of the 30-mile stretch of the Narbada River. A total of about 20,200 kg. fish valued at Rs. 22,164 are estimated to have been landed at the two centres from August 1958 to March 1959. The fishery of *Barbus* (*tor*) *tor* was more important at Hoshangabad (30·15%) with *L. fimbriatus* contributing 10·3% and *C. mrigala*, *C. catla* and *L. rohita* small percentages. At Shahganj the fisheries of *Barbus* (*tor*) *tor* and *L. fimbriatus* were almost equal (19·73 and 19·43%) and *C. catla* and *L. rohita* were totally absent. *Rita pavimentata*, however, was the most predominant fish at both the centres among the cat-fishes, but at Hoshangabad it contributed to only to 12·94% of the total catches as against 24·29% at Shahganj.

Observations on catch-per-unit-of-effort for two main types of fishing gears, namely, long lines and cast nets, were made at Shahganj centre. 228 long lines for a total period of 2,577 hours and 151 cast nets for a period of 1,324 hours produced an average catch of (per 500 hooks per hour) 0·17 kg., as against 0·543 kg. per cast net per man-hour. The maximum catch-per-unit-of-effort for both the types of gears was in July–September and lowest in January–March. Drag nets were operated in December 1958 and March 1959. Average catch-per-net-per-man-per-hour for the two months together was 15·94 kg. Stomach contents of 419 specimens of *Rita pavimentata* were analysed and the feeding activity was found to decline progressively from July to February. The principal diet of the fish consisted of Prawns (12·3%), Molluscs (11·4%), Teleosts (10·9%) and Insects (9·4%). The juveniles (up to 120 mm.) subsisted mainly on insect larvæ and adults. Examination of gonads and ova diameter of the ovaries indicated that the fish breeds from July–September.

250 miles of Narbada (both banks) in Madhya Pradesh from Hoshangabad to Mandla, and 90 miles in Bombay State from Broach to Surpan were surveyed. Of the 292 villages in the 250-mile stretch in Madhya Pradesh, 157 are fishing villages with a total population of 26,608 persons, 1,824 being active fishermen. The fishing gears in the fishing villages were scoop nets (1,561), cast nets (3,279), gill nets (1,071), drag nets (17), long lines (3,373) and fishing rods (258). The number of boats available in these villages are: large (above 20′): 53, Medium (11–20′): 2,150, and small (up to 10′): 359. Out of 113 villages surveyed in the 90-mile stretch of Bombay State,

63 were fishing villages with a total population of 6,950, of which 482 were active fishermen. The fishing gears were scoop nets (1,623), gill nets (1,723), bag nets (300), drag nets (158), cast nets (217), long lines (1,306) and traps (12). The number of boats was Large: 233, Medium: 115 and Small: 4.

Day-to-day observations on the availability of carp seed from Narbada River at Hoshangabad were made for 28 days in July–August 1958. About 5,80,000 carp fry were collected from three fry collection nets in 84 hours. The percentage of major carps, comprising *L. fimbriatus*, *C. catla*, *C. mrigala* and *L. calbasu*, were extremely poor. The collections consisted mainly of fry of *C. reba* and *L. bata*.

Collections of fairly large number of hatchlings, larvæ and juveniles of *Barbus* (*tor*) *tor* were made in the first week of September 1958 for the first time during monsoon season. This clearly indicated that the breeding of this species commences in August–September. This was further supported by the partly spent condition of the ovaries in September. Collections of fry measuring 15–25 mm. in total length, caught from Narbada River during September 1958 to January 1959, have shown that in all probability the breeding period of this species of Mahseer extends over 3–4 months from August–September onwards.

13. *Krishna-Godavari survey*

A preliminary survey of the two systems to evaluate their fisheries resources was completed in April 1958 and Rajahmundry was selected as the Unit's Headquarters. The staff appointed under the scheme was given extensive training at Allahabad in survey and research investigations and posted at Rajahmundry from March 1959.

Rajahmundry is served by two main markets and catches during March have been estimated to be 12,422 kg., of which carps formed 31·05%, cat-fishes 15·99%, prawns 19·67% and miscellaneous 33·29%.

The fishermen population of Rajahmundry and Dowleswaram is 319 and 250 respectively. The fishermen at Rajahmundry use cast nets (159) and drag nets (4) only, whereas at Dowleswaram cast nets (29), Rangoon nets (125), Kathuwala or Theluvala (2) and Jariguvala (500) are used.

14. *Lacustrine investigations at Tungabhadra Dam*

During the year under report 20·67 metric tons of fish were sold at Hospet fish market. Predominant species were *Barbus kolus*, *Labeo fimbriatus* and *Barbus dobsoni*.

Fishing in the Tungabhadra reservoir is not organised and hence the Research Unit operated Uduvalai and Rangoon nets with the help of two fishermen and a coracle. This fishing was done on 134 days and a total of 467·2 kg. fish was caught, the average daily catch being 3·45 kg.

All the specimens of *L. fimbriatus* caught were immature and their guts were invariably empty. Scales collected from fishes from the market were examined for growth studies. The average length attained at the formation of different rings is as follows: 1 ring—172·3 mm.; 2nd ring—259·3 mm.; 3rd ring—339·4 mm., 4th ring—418 mm.; 5th ring—488 mm. and 6th ring—563·3 mm.

963 specimens of *Barbus kolus* were examined and it was seen that the food of the adult consists mostly of gastropods, followed by copepods, insect larvæ and ostracods. Young ones below 110 mm. feed mostly on *Cyclops*, *Diaptomus* and *nauplii*. The fish breeds throughout the year with a peak during June–July. The fingerlings have been collected during the months of April, May, June, July, August and September. The female matures when it reaches 3 years of age and is nearly 230–300 mm. in length. The number of mature eggs in an ovary varies from 1,430 to 9,500. The male matures earlier than the female. The growth in the male and female is nearly same and the lengths attained at different ages are as follows: 1st scale ring is formed at 51–140 mm.; 2nd ring at 121–200 mm.; 3rd ring at 151–250 mm.; 4th ring at 211–300 mm.; 5th ring at 261–340 mm.; 6th ring at 311–80 mm.; and 7th ring at 351–410 mm.

The food of *Barbus pinnauratus* consists mainly of *Spirogyra*, diatoms, insect larvæ and molluscs. Like *B. kolus* this fish also breeds throughout the year with peak in April and the number of ripe eggs varies from 24,455 to 1,52,655. Growth studies on scales show that the 1st ring is formed at 90–110 mm. length, 2nd at 145–60 mm., 3rd at 185–90 mm., 4th at 235–50 mm., 5th at 270–80 mm. and 6th at 310 mm.

27 specimens of *Barbus tor* were studied. They were caught in Rangoon nets only and not in Uduvalai. The average size of fish caught in different meshed nets is as follows:

1″ mesh—20·7 cm.; 2″ mesh—40·8 cm.; 2·5″ mesh—52·4″ and 3·5″ mesh—58·2″.

Barbus dobsoni feeds on molluscs and vegetable matter. The gonads in all the fishes caught were in immature condition.

Over 700 specimens of *Rohtee vigorsee* were examined and the food was found to consist of insect larvæ, small gastropods, fish fry and zooplankton. The ratio of male to female was nearly 1 : 5. Females in running condition of gonads were found in May. The number of mature eggs varied between 10,580 and 98,980. The fish appears to have a prolonged breeding season from April to October.

The age and growth studies on scales show that 1st ring is formed at 69·9 mm. average length, 2nd at 110·3 mm., 3rd at 170·2 mm., 4th at 222·2 mm., 5th at 272·8 mm. and 6th at 308·2 mm.

68 specimens of *M. seenghala* were examined, most of which had unripe gonads. Majority of them were caught in Rangoon nets of 1·5″ and 2·5″ mesh. The food consists of teleosts, specially *Chela* spp. and young ones of *Glossogobius giuris* and insect larvæ.

112 specimens of *Silonia silondia* were examined, of which 69 were caught in the month of May 1958 only. The fish feeds mostly on minnows. The cleitherum bone shows very good growth marks. The first mark appears at 170–90 mm. length, second at 240–60 mm., third at 290–320 mm., fourth at 345–65 mm., fifth at 404–60 mm., and sixth at 470–500 mm.

Efforts were made to locate the areas of spawning of fish in the reservoir and its inlets—the Hirahalla and Chilka Hagari River. Fry and fingerlings of major carps were not collected in the tow net in the reservoir. The fry of *L. fimbriatus* (14–53 mm.) were collected from the river and fry of *Catla* from Raya canal which joins the Kamalapuram tank.

Studies on the fisheries of Krishnaraj Sagar have also been started and experimental fishing was done for 5 days during the month of March 1959. A total of 17 nets (six Rangoon nets and 11 Uduvalai nets) were laid daily.

Studies on bottom fauna were made in the reservoir and collections obtained at different depths up to 20 meters. Gastropods and dipteran larvæ are found at all depths. Mayfly larvæ were found up to 10 metres. Chironomids and Mayfly larvæ were present at all periods except July–September. Other organisms were present throughout the year.

Plankton studies were made at the surface and at 2, 4, 6, 8, 10 and 12 metre depths. Blue–green algæ predominated in the phytoplankton and was followed by green algæ and diatoms. Maximum concentration was found during the months of May and June. Zooplankton was at its maximum during May and November.

Maximum surface temperature (30–31° C.) was during April and May and minimum during December and January (25° C.). There was indication of thermal stratification during April and May between 4–6 metre depths and again during March 1959. The temperature near the 20 metre depth was nearly 2–3° C. less than surface temperature. pH varied between 8·2 and 8·4. Due to floods, turbidity was high (8″) during July and August. Later, the water became clear and lowest turbidity was found during January (76″).

Estuarine Division

15. *Investigation on the fisheries of the Hooghly, Matlah and Mahanadi estuaries*

The fisheries in all the three estuaries were slightly better than during the previous year but were much poorer than in normal years. The monsoon fishing for *Hilsa* was extremely disappointing in both Hooghly and Mahanadi. During the winter season for a very short period appreciable catches were made in the Sunderbans and certain areas of the Mahanadi estuaries, but for the rest of the period fishing was very poor. As the bag net fishery in the lower zone of the Hooghly was also very poor, the winter fishing camps broke up earlier than usual and only less number of fishing units operated in the area.

The combination of sampling survey and total enumeration methods were continued to estimate the total catch and catch-per-unit-of-effort of the three estuaries. The data for the Hooghly and Matlah were compiled and are summarised below:

Zonewise total catch figures of Hooghly and Matlah estuaries

	Weight in kg.
Hooghly estuary—	
Zone I ..	10,28,488·56
Zone II ..	2,65,694·02
Zone III ..	14,76,832·44
Zone IV (Rupnarain) ..	2,84,812·94
Total ..	30,55,827·96
Matlah Estuary—	
Zone I ..	2,63,501·80
Zone II ..	3,30,640·74
Total ..	5,94,142·54
Grand Total ..	36,49,970·50

The inventory of the fishing units of the Mahanadi estuary was almost completed during the year. It was estimated that there are about 5,020 fishermen with about 45,833 nets of different types, fishing in the area.

The estimation of total catches of Mahanadi is in progress but a general increase in total landings is apparent as shown by the statistics of total quantity of fish exported during the year which was estimated to be 2,57,970 lb. (1,17,013 kg.) as against 1,86,900 lb. (84,776 kg.) in 1957–58.

A comparison of the fisheries of the three estuaries for the whole year brings out many interesting features. The bulk of the annual landings from the Hooghly is composed of *Hilsa* (about 55%) while there is hardly any *Hilsa* fishery in the Matlah estuary. It would appear that on account of the lack of an adequate supply of head waters, *Hilsa* does not ascend this estuary. Sciænids and cat-fishes form the other two important groups. In Matlah, crabs and perches contribute to the major portion of the catches, cat-fishes and miscellaneous clupeoids also being important constituents. Matlah contributes to a greater production of prawns and shrimps as also Polynemids. In Mahanadi the fishery is mainly for Bhekti, Mullets and Polynemids and the catch of miscellaneous fishes is markedly low, mainly on account of the selectivity of the nets operated.

16. *Analysis of commercial catches*

As during previous year, regular studies of samples of commercial catches collected at fortnightly intervals from selected sampling centres in the estuaries were carried out to provide the primary data for understanding the population characteristics.

Hilsa ilisha formed the most important species in Clupeoid group and details regarding this species are given under the section dealing with *Hilsa* investigations. Among other clupeids *Setipinna phasa*, *Anchoviella tri* and *Coila* spp. were the more important forms.

Setipinna phasa was represented mainly in the catches from the upper and middle zones of the Hooghly estuary by '0', I and II year groups. The '0' group dominated as in previous years, but I and II year groups which usually form the main spawning stock were comparatively rare. New recruits to the fishery ('0' group—modal length 8·5 cm.) appeared during the months of May and June. Availability of mature and spent specimens in the catches only during the months March–June and the appearance of early size-groups during subsequent months confirms the observation that the fish spawns during the pre-monsoon months (March–June). Prawns, copepods and

other fish formed the main food of the species. The feeding activity was found to be rather low during the year.

Anchoviella tri occurred in large numbers at Port Canning in Matlah throughout the year. Juveniles ranging in length from 21 to 77 mm. dominated the catches. In the Hooghly estuary the fish were comparatively scarce and were represented only in the catches from the lower Sunderbars. Copepods, cladocerans and diatoms formed the main food of the species. *Anchoviella indica*, which in the previous year formed a sizeable fishery, was almost totally absent. *Coilia ramacarati* and *C. borneensis* were mainly found in the catches from the lower Sunderbans. The size range was between 23 and 192 mm. Juveniles having a modal length of 50 mm. entered the fishery in the summer months and they had fed mainly on copepods and the adults on fish, prawns and copepods.

Mugil corsula, *M. cunnesius*, *M. parsia* and *M. tade* were the species of mullets that contributed to the fishery. Of these *M. corsula* was caught in all the zones of the estuary and others were restricted to the lower zone only. *M. corsula* was represented only by '0' group individuals in the upper or middle zones, whereas maturing and mature I and II year groups were caught only from the lower zone. In the other species also, the dominant class was '0' year group and the smaller size-groups entered the fishery in the winter months. Adults of *M. parsia* belonging to I and II year groups were found in the catches from lower Sunderbans during winter. *M. tade* was represented in the catches by three distinct groups having modal lengths of 68, 125 and 300 mm.

Polynemus paradiseus formed the most important species among threadfins in the catches, particularly from the middle and upper zones of the Hooghly and from Matlah, whereas *Polydactylus indicus* and *Elutheronema tetradactylum* were caught mainly from the lower zone. The fishery of *P. paradiseus* continued to be poor this year also. Mature and maturing individuals of the I and II year classes, of which the former was dominant, were represented in the catches during the earlier part of the year (March-April). The smaller size-group ('0' group with modal length of 3·5 cm.) fishes entered the fishery in the months of May and June. Only immature '0' group individuals of *E. tetradactylum* and *P. indicus* were represented in the catches sampled in the estuary. Large-sized mature individuals were caught in good numbers in the lower Sunderbans during the winter months.

Lates calcarifer which is the most important perch of brackishwater areas was caught in greater abundance from the Matlah and Mahanadi estuaries. It was rarely found in the catches of the Hooghly though

abundant in the enclosed brackishwater waters fed by this estuary. The unsuitability of the gear employed appears to be the reason for the scarcity of this species in the catches from the main estuary. Experimental fishing with more effective gear is proposed to be carried out for this species with the Estuarine Research and Exploratory Fishing Vessel recently obtained. The commercial catches from the Hooghly and Matlah consisted mainly of two and three year size-groups, whereas in Mahanadi all the year groups were represented in the catches.

Maturing and mature *Sillago panijius* were caught during this year also in the winter months from the lower reaches of the Hooghly and Matlah estuaries. Juveniles with a modal length of about 4·0 cm. occurred in the catches from the rest of the estuary throughout the year.

Cat-fishes represented by about 20 different species formed a very important group contributing to the fishery throughout the estuarine system. *Mystus gulio* was represented in the middle zone during June–September and in the lower zone during the winter months. There was a decline in the catches of the species during the year as compared to the previous year. The features that characterised the year's fishery for the species were a marked numerical decline in the advanced '0' group fishes (modal length 77 mm.) which resulted from previous year's spawning; a similar rarity of the I year group (modal length 120 mm.) which in previous years constituted the main spawning group; very low recruitment to the fishery of the smaller size-groups in the post-spawning months (October–December) and absence of II and III year classes (from the fishery) which also in previous years contributed to the spawning stock. The species fed actively during all the months of the year on prawns, megalopa larvæ, insects and fæcal matter. *Pangasius pangasius*, the general trend of the fishery for which was more or less identical to that of the previous year, was represented in the catches of the middle and upper zones of the estuary almost throughout the year. '0' to IV year classes comprised the fishery, of which '0' group predominated. '0' year classes formed the new recruits entering the fishery in the upper and middle zones of the estuary during August–December. The II and III year groups, which usually enter the fishery of the middle zone during summer months were comparatively scarce this year. During winter months in the lower Sunderbans, II, III and IV year groups (modal lengths 195, 230 and 250 mm. respectively) contributed to the fishery and of these, the II year class was dominant.

Osteogeneosus militaris was represented in small numbers in the catches from the lower Sunderbans during winter months by advanced '0' group fishes (modal length 95 mm.). During summer months I and II year classes

(modal lengths 125 and 230 mm. respectively) constituted the fishery in the middle zone, of which I year group was dominant. The noteworthy features in the year's fishery were: a predominance of I year class, which in previous years were absent in the middle zone; a numerical decline of the II and III year classes which in previous years constituted the main spawning stock; comparatively low recruitment of '0' group individuals in the upper reaches of the middle zone instead of in the lower reaches as in previous years. The smaller size-groups of the species (50–100 mm.) fed on copepods and small prawns, whereas the adults subsisted on fish and prawns. The feeding activity appeared to be low during monsoon and high during winter months. *Tachysurus jella* afforded a good fishery in the lower Sunderbans during winter months. In the middle zone of the estuary '0', I and II year classes entered the fishery during March–August and of these the '0' group was dominant.

Harpodon nehereus formed an important constituent of the fishery in Matlah during all the seasons except winter. Appreciable numbers of the fish were caught in the lower Sunderbans in the Hooghly estuary during winter months. The catches consisted mainly of juveniles (72 mm. modal length). Mature specimens ranging from 132 to 279 mm. were also available in the lower zone of the Hooghly. Smaller fishes, prawns and megalopa larvæ formed the main food of the species.

Trichiurus savala, *T. haumela* and *T. muticus* were the three species of ribbon fishes in the catches, the first being the most abundant. The fishery of all these species was confined to the lower zone of the Hooghly estuary and Matlah, where they were caught in large numbers during September–March. The size of *T. savala* in the catches ranged from 16·1–42·0 cm., of which 75% of the specimens examined were immature and rest mature. Most of the mature specimens had gonads in the III stage of maturity. No oozing or spent specimens were obtained. *T. haumela* ranging in size between 18·1 and 41·0 cm. were represented in the catches in lesser quantities. *T. muticus* ranging in size from 14·0 to 34·0 cm. were caught in very small numbers. Prawns and small fishes formed the food of the species.

Pama pama was the most common species of jew fish in the catches of the Hooghly estuary. The species was absent in the catches from Matlah. The '0' age-group ranging from 10 to 70 mm. was predominant in the upper and middle zones during the months, October–March. Larger size-groups having a modal length of 25·0 cm. were caught in large numbers in lower Sunderbans during winter months. Maturing fish over 15·0 cm. in length were obtained in the catches during March–August and oozing and spent

fish in June and July. Fishes, prawns, megalopa larvæ, copepods and cladocerans constituted the food of the species. *Sciæna coitor*, *S. balengeri*, *S. ossea*, *S. vogleri*, *S. biauritus* and *Otolithus maculatus* were the other species of jew fishes that were caught, mainly in the lower zone of the Hooghly and Matlah during the winter months.

Gobeids, represented by *Glossogobius giuris*, *Apocryptes bato* and *Odontoblyopus rubicundus*, were the only group among the miscellaneous fishes that contributed appreciably to the fishery. These fishes were found mostly in the upper zone of the estuary throughout the year, where the juveniles of all these species formed a considerable part of the bag-net catches.

Study of the samples of prawn catches of previous years completed during the period shows that both in the Hooghly and Matlah estuaries, *Palæmon mirabilis*, *Leander styliferus*, *Metapenæus brevicornis* and *Parapenæopsis sculptilis* formed appreciable proportion of the catches. In the lower stretches the majority of the prawns consisted of *Leander styliferus* and *Metapenæus brevicornis*, both of which together forming about half the total catch from the entire estuarine region during the winter months. One interesting feature noticed is the scarcity of *Penæus semisulcatus* in the catches from the estuaries even though it is one of the most important estuarine prawns of the area. It is found that the majority of the prawns of this species brought to the assembling centres and markets are caught from the embanked brackishwater areas, where they enter as juveniles. It appears most likely that unsuitability of the fishing gear is responsible for the scarcity of this prawn in the catches. Exploratory and experimental fishing is therefore proposed to be carried to determine whether there are unfished resources of this prawn in the estuaries.

Observations carried out throughout the year indicate that *Palæmon carcinus* migrates down the estuary and breeds in the neighbourhood of Uluberia during the period March–June. Study of the commercial catches show that during this period mature and berried individuals occur in the area. Experimental fishing has to be carried out to delimit the breeding grounds and assess the extent of fishing intensity brought to bear on the stock.

17. *Hydrobiological observations*

In the main Hooghly estuary, the surface temperature of water ranged from 21·0 to 33·7° C. during the year, while the temperature in Rupnarain, Matlah and Mahanadi varied between 20·5–33·1° C. and 20·8–33·5° C.

respectively. In the Hooghly the salinity of water in the region above Diamond Harbour was in traces during August and September. On the basis of salinity data, the entire stretch between Fraserganj and Medgachi in Hooghly could be divided into three zones. An upper stretch (area above Khusigoli which had only traces of salinity throughout the year), a middle stretch (comprising the area between Diamond Harbour and Khusigoli which has a salinity range from traces to 25·7‰) and a lower stretch (the area below Diamond Harbour which has a salinity range between 2·0 and 34·2‰).

Qualitative and quantitative analyses of plankton from Hooghly, Rupnarain and Matlah were continued. Compared to the previous year there was a further decline in plankton production in the Hooghly estuary, whereas in Matlah the production remained steady. This appears to bear relation with the poor fisheries of the estuaries during the last two years. Production of plankton in Rupnarain improved slightly till June and thereafter declined. Plankton production in the upper zone and lower zone was higher than in the middle zone. Freshwater forms predominated in the upper zone, whereas in the lower zone marine forms dominated. In the middle zone both freshwater and marine forms were present.

Among the important phytoplankters in the upper reaches of the Hooghly estuary were *Coscinodiscus*, *Melosira*, *Spirogyra* and *Oscillatoria*. Copepods rotifers, and nauplii predominated in the zooplankton. In the lower reaches Diatoms, mainly *Coscinodiscus*, *Chætoceros* and *Thalassiothrix* predominated in the phytoplankton whereas larvæ of various organisms were dominant in the zooplankton.

18. *Studies on the productive potential of brackishwater bheris*

Studies on the distribution and cycle of abundance of benthic algæ were continued in selected brackishwater bheris in Sunderbans. Study of correlation between algal production and the temperature, salinity and nutrients, both in the soil and water phases was done. The bheris selected for observations were of three categories as far as algal production was concerned (*i.e.*, high, low and medium productivity). The water phase was examined for temperature, salinity, alkalinity, phosphate, nitrogen, potassium, calcium and magnesium and the soil phase was tested for nitrogen, potassium, phosphorus and sulphide. It was concluded on the basis of observations that for good growth of algæ in the bheris, salinity should be above 10‰ and nitrogen, phosphorus and potassium should not be in limiting concentrations. Further, in a good bheri N, P, K was observed to be above 17·7 mg./100 gm., 3·8 mg./100 gm. and 55·3 mg./100 gm. (of soil) respectively.

Studies on the periodicity and seasonal changes of algæ in the bheris showed that blue-green algæ dominated during post-monsoon and early winter months, while green algæ dominated during late winter and early summer months.

19. *Studies on the maturity, breeding and early development of estuarine Palæmonid prawns*

Regular examination of samples collected from various parts of the Hooghly estuary showed that *Palæmon rudis*, *P. mirabilis* and *Leander fluminicola* breed almost throughout the year. *Leander styliferus* and *L. tenuipes* breed only in the more saline lower stretches of the river, though the embryos do not actually hatch out there. *P. carcinus* congregates in the neighbourhood of Fuleshwar from the latter half of March–June when the catches from the area consist mainly of berried females. *P. malcolmsonii* and *P. scabriculus* are more abundantly found in the upper stretches near Khasbati and Medgachi, where during monsoon months and early winter, berried females occur in appreciable numbers. The period of incubation varies from 15 to 22 days in different species. *P. lamareii* eggs are comparatively large and the larvæ hatch out in fairly advanced stage with all appendages already formed. It undergoes three rapid moults to reach the stage when it resembles adults. The stage I and stage II larvæ of all the other species are very similar in appearance but for slight differences in the colour of the chromatophores on the 3rd abdominal segment. Observations on the maturation of *P. carcinus* show that the ovaries begin to mature by early March. From April to early part of June fully mature and ovigerous individuals are found. The pattern of ova maturation indicates that a single female spawns more than once in the season.

20. *Rapid survey of Pulicat and Kerala backwaters*

Pulicat lake is a shallow stretch of backwaters, approximately 178 sq. miles in area connected to the sea by three main openings at its southern tip and several smaller inlets in the northern half. About 3,000 fishermen work in various parts of the lake and sixteen different types of gear are operated making a total of 3,891 nets, but of these only 'Badivalai' (shore seine), (boat seine) and 'Koduvavalai' (gill net) are important.

From the collections made in March 1959 it is found that salinity in the lake varies in different localities from 12·30‰ (off Venadu) to 37·12‰ (off lake mouth at Pulicat). pH varied between 6·9 (at Irakam) and 8·0 (at Annamalaicheri).

40 different species of fish, 3 prawns and 2 crabs were observed to be caught by the commercial fishermen during the survey. Mullets and prawns constitute the major portion of the catches from the lake. It is estimated that in and around Pulicat village only (an area of approximately 40 sq. miles), 7937·87 metric tons of fish and 907·18 metric tons each of crabs and prawns are landed yearly. The total annual production of the lake is estimated to be about 18,14,360 kg.

A preliminary survey of the Kerala backwaters was initiated in the month of March 1959 for studying their fishery potential. A survey of the largest piece of backwaters, *viz.*, the Vembanad lake and connected waters, extending from Cranganore in the north to Alleppey in the south, a distance of about 60 miles and covering an area of roughly 100 sq. miles, was carried out during the year. The backwaters are in most places shallow, with depths at fishing grounds varying from 1 to $7\frac{3}{4}$ metres. The bottom is mostly muddy with an admixture of fine sand in some places.

The northern sector of the lake is much more saline than the southern portion because of its two connections with the sea and shows a salinity range of 23·31–33·55‰, while the waters south of Vaikom show a general decline in salinity (18·44–10·49‰). During the rainy season the water remains fresh for about 4 months up to Thannirmukkam in the southern sector.

Fishing is done all over the lake throughout the year. The fishing is controlled by the Government by a system of leasing and licensing. Among the most numerous and conspicuous nets are the Chinese dip nets and the stake nets, the licensing of which brings in a revenue of about Rs. 1,10,000 to the State.

In the northern sector above Arukutty, the main fishery seems to be that of prawns and mullets. At Azhikode large-sized mullets are caught in the dip nets. In the lower stretches, the fishery is dominated by the Bhetki, the Milk-fish and the Pearlspot, large- and medium-sized *Sciænids*, *Engraulids* and cat-fishes. The survey also revealed the existence of an occasional Hilsa fishery in the backwaters. It is estimated that a total of about 10,160 metric tons of prawns are caught annually in the lake.

21. *Investigations on the Hilsa fisheries of India*

As during the previous year, Hilsa fisheries were extremely poor during this year also. The migration of Hilsa up the river in the Hooghly during

the monsoon season was unusually delayed and this is attributed to the late and scanty rainfall in the area. The winter fishery was also extremely poor. However, in December there was a sudden revival of the winter fishery for Hilsa in the Sunderbans area and in the coastal areas of Midnapore. Nearabout Fraserganj alone about 11–13 metric tons of Hilsa were caught per day. This fishery, lasted only for about a week and came to a close as abruptly as it had started and was of added significance in view of the fact that the winter Hilsa fishery was a complete failure in the area during the preceding two years. Environmental studies conducted showed that coinciding with the Hilsa fishery, there was a marked increase in phytoplankton, especially the Diatom *Coscinodiscus*. The bloom lasted for about 10 days only. This observation has given added support to the inference arrived at from last year's studies, that probably the quantity of plankton in the Sunderbans area is an important factor that determines the success or failure of the Hilsa fishery.

In the Godavari and Krishna Rivers as also the Ganga, the fishery was extremely poor. However, it is reported that Bramhaputra afforded very lucrative fishery during the year. Sampling surveys to estimate the total catch and catch-per-unit-of-effort of Hilsa from the Rivers Godavari and Padma were conducted by the survey staff of the Hilsa Research Programme. An inventory of the Hilsa fishing units of the Krishna River was completed and a suitable sampling programme was devised to estimate total catches and catch-per-unit-of-effort from the river. Arrangements were finalised to obtain regularly the required catch data from other areas where comprehensive fishery investigations are now under way. Training was given to two officers deputed by the Fisheries Departments of Andhra and Assam in sampling survey methods for the collection of Hilsa statistics, with a view to collect the required data through the State Fisheries Departments in these two States.

The Hilsa catches from the Hooghly estuary during the period April–December 1958 was estimated to be 5,31,698 lb. (2,41,192,12 kg.). During the same period the catches from Lalgola amounted to 18,095 md. (6,56,617 kg.). The catches from the Godavari were extremely poor and amounted to only 17,062 kg. The catch per unit effort figures of the Hilsa fishing units operated in the Hooghly are reported elsewhere. The data for Padma are as follows:

Name of fishing unit	Hilsa catch-per-unit-of-effort in kg.	Percentage of Hilsa in relation to the other species caught in the nets
		%
Sanglo jal ..	1·85	100
Chandi jal ..	5·35	89
Kona jal ..	5·50	72
Kharke jal ..	0·56	100
Bauli jal ..	1·12	100
Chota jagatber jal ..	4·01	19

In the Godavari, Hilsa were caught in small quantities in all the 4 centres of observation. The Rangoon net was the main net operated at these centres during the quarter and the entire catch of this net consisted of Hilsa.

The four-year age-group predominated in the catches from the Hooghly, Padma and Godavari. In Padma, however, a fresh year group of two-year old fish entered the fishery in October 1958 and gained prominence over the older age-groups by December 1958.

The analysis of the morphometric data collected so far to delimit the Hilsa populations is nearing completion. The clusters of morphometric characters obtained during last year by the use of distance functions do not appear to signify either any genetic relationships or similarity in environmental conditions. The analysis of variance and covariance of non-meristic data shows that the populations of Hilsa of Ganga, Padma, Chilka, Godavari, Cauvery and the Saurashtra coast can be distinguished from the Hilsa of the Hooghly by the regression of head length or total length alone, though there are other singificantly different characters also. Similarly the population of Bramhaputra, Krishna and Narbada can be distinguished by the regression of body height alone. On the basis of total number of vertebræ, the Hilsa of Cauvery and of Saurashtra coast can be recognised from the rest. The average number of vertebræ for Cauvery samples is 44·5 and for Saurashtra 45·5; whereas it is less than 44·5 in samples from all other areas. The populations from Krishna River and Ganga can be distinguished from the others by the average number of trunk vertebræ which are 12·1

and 12·48 respectively. Populations of Chilka, Bramhaputra and Narbada can be distinguished by the average number of caudal vertebræ without hæmal spines, which are 11·24, 11·52 and 11·8 respectively. The stock of Padma can be distinguished from the others by the low average number of vertebræ with duplicate neural spines (20·5).

The fishermen and the fish traders generally differentiate Hilsa from different river systems by their taste which seems to be mostly based on fat content of the body. With a view to determine whether there are any significant differences in the fat contents of fish from different river systems, analyses of samples were carried out. Mature male and female fish in the VI stage of maturity collected during the breeding season only were utilised for the study. A minimum of 8 samples of male and female fish were analysed from each river system. The data obtained so far are given below, which show significant differences in fat contents of fish from different environments.

Origin of sample	Average percentage fat content		
	Female	Male	Total
Krishna River ..	11·70	17·50	14·48
Godavari River ..	9·70	13·60	10·70
Saurashtra coast ..	15·46	23·10	16·73
Narbada River ..	5·40	5·40	5·40
Mahanadi River ..	18·40	21·05	19·28
Padma River ..	14·07	14·70	14·40

To enable large-scale tagging of Hilsa, an inexpensive nylon streamer tag was designed and hand-fabricated with mostly locally available material. The tag which consists of a rectangular Vinyl Plastic strip, 35 × 12 mm. with the necessary explanatory legend written by hand with Vinyl Stamping Black Ink and a braided nylon streamer, costs only about a Rupee per hundred. After a series of preliminary experiments a suitable method of tagging Hilsa was evolved. The fish, collected immediately after capture from the fisherman's net, is placed in a specially prepared fish cradle lined with plastic foam lining to prevent any injury to the fish, immersed in a tub of

water. The tag is tied behind the dorsal fin by piercing the dorsal musculature by means of a surgeon's needle. This type of tagging did not injure the fish in any appreciable manner and the examination of recovered fish has confirmed this. A total of 760 fish were tagged and released in the Hooghly, Padma and Ganga Rivers during the year. So far about 7·76% of the tagged fish have been recovered. The recovery is very satisfactory in the Hooghly area where it has been possible to carry out fairly intensive propaganda. The results of the experiment obtained so far seem to indicate that the direction of migration of mature or maturing Hilsa is not always up-river as generally believed. A number of tagged fish have been recovered from downstream fishing grounds also. One fish marked near Chinsurah in the Hooghly, travelled downstream (a distance of 70 miles) and then ascended the Rupnarain a distance of about six miles. One Hilsa tagged in Lalgola in the Padma had migrated up-river a distance of about 260 miles in about two and a half months' time.

Survey to assess the abundance of young Hilsa in the Hooghly was continued. Comparative experiments conducted for the purpose of evolving a standard method of operation of bag nets for working out an index of abundance have shown that the figures of catch per high tide, obtained by the operation of a bin jal with the upper margin of the net above the surface of water, would be a suitable criterion for studying abundance in different years, seasons or localities. The average catch per high tide during the year in Barrackpore, where the experiments were conducted, was 38 fish. In low tide the average was only 9 fish. It is proposed to expand such surveys to other areas also to assess the abundance of young fish and of fresh recruits to the fishery.

Chilka Lake Investigations

22. *Fisheries of the Chilka lake*

A total of 38,37,915 kg. of fish has been estimated to have been obtained from the Chilka lake during 1958 against 44,11,249 kg. during 1957. Of this, prawns constituted 30·42%, mullets 20·97%, clupeids 16·39%, cat-fishes 10·46%, sciænids 6·98%, threadfins 5·74%, perches 5·00% and the rest 4·04%. *Mugil cephalus* (14·37%) and *Liza troschelli* (4·16%) formed the more important fishery of the mullet group. Among the prawns, *Penæus indicus* formed 21·65% and *P. semisulcatus* 6·76%. *Mystus gulio* was the most important among cat-fishes contributing 6·49% of the total production and *Tachysurus arius*, *Osteogeneiosus militaris* and *Plotosus canius* together making up 3·47%. *Hilsa* and *Nematalosa* contributed 7·35% and 5·00% respectively. *Pseudosciæna albida*, *Eleutheronema tetradactylum* and *Lates*

calcarifer formed 6·27%, 5·74% and 3·53% respectively of the total catches. A month-wise analysis of production shows that in the year 1958, October was the leanest month of production (3·58%) and December the biggest (11·31%). The enclosure trap fisheries called Jano, producing large quantities of mullets, were operated in the latter. During April–August the production varied from 8·74 to 11·0% of the total catches.

23. *Biological observations on commercial fisheries*

Mugil cephalus formed 68·4% of the total production among mullets, followed by *Liza troschelli*. Observations in 1958 confirmed those of 1957 and the opinion of earlier workers that the species undertakes regular breeding migration into the sea largely during the months October–December. Relatively large-sized mature specimens migrate away from the sea early in the season and progressively smaller ones are left to migrate later as the season advances. The seaward migrating males are interpreted to be mostly about 1 year old and the females two and more. Large-scale inward migration occurs in fingerlings. A few fingerlings (40–71 mm.) were recorded entering the lake in January 1959 and during 1958, bulk of the advanced fingerlings entered in May and June. A few large-sized individuals of *M. cephalus*, showing spent recovering ovaries enter the lake along with the fingerlings. In June 1958, ten such large females were found in a haul estimated to have about 1,320 advanced fingerlings. A regular seaward breeding migration of *Liza troschelli* has also been confirmed during the year under report. Bulk migration of this species occurred in January 1958 and also in December–January 1958–59. The majority of seaward migrating *L. torschelli* are interpreted to be one year old and females one and two years. In May 1958, a few fingerlings, 70–78 mm. in length and in June 1958 another lot 65–80 mm. in length, were observed close to the lake mouth. In March 1959, a large number of fingerlings of the size range 96–243 mm. entered the lake from the sea, the mode being at 163 mm. class.

Penæus indicus formed 71·2% and *P. semisulcatus* 22·2% among prawns. Size frequency data on 7,323 specimens of *P. semisulcatus* collected in the main body of the lake and outer channel are on record. In September 1958, post-larvæ of this prawn measuring 9–15 mm. were collected in the sea close to the lake mouth. Some specimens of slightly larger sizes have been collected in the outer channel from August 1958 onwards and still larger ones in the main body of the lake. In April 1958 tens of maunds of *P. semisulcatus* were caught in the outer channel where there were insignificant catches in the earlier months. In the case of *P. indicus* also it was possible to catch post-larvæ measuring 8–13 mm. from the sea close to the lake mouth. It

has been confirmed that both these species of prawns depend on sea for the completion of their life-cycles.

Hilsa ilisha formed 44·9% and *Nematalosa nasus* 30·6% of the production among Clupeids in the year 1958. Year-round observations on *Nematalosa nasus* have shown that the species ripens when one year old and breeds in the lake during the period May–July. New recruits (zero group) enter the commercial fishery in August forming a very conspicuous mode centred at 67·8 mm. class. Breeding largely occurs in the Southern Sector of the lake. Observations made in 1958–59 have confirmed those of the previous year that one-year-old individuals grow to about 180 mm. total length and two years old to about 250 mm. total length. The maximum size at maturity is 131 mm. and the average size at first maturity is 171 mm. Lake mouth observations have shown that large-sized individuals from the sea of the size range 112–342 mm. add to the stock of Chilka *Namatalosa* from November-June, largest number having been recorded during April. The available data show that the zero year class enter the commercial fishery in September at 62·5 mm. class and form a very conspicuous mode at 133·5 mm. class in November–December. Yet another peak at about 312·5 mm. class represents specimens about 1¼ year old. There is evidence to show that stocks of Hilsa of the size range 213·5–488·5 mm. from the Bay of Bengal add to those of the Chilka during the period January–August. Young Hilsa 22–24 mm. and spent individuals were recorded in the outer channel in March 1959. Fingerlings of Hilsa were also encountered in the Northern Sector of the lake in March–April 1959. These observations show a double breeding of Hilsa, once in January and next in July–August–September. These observations need further confirmation.

Threadfins formed 5·74% of the total production in the year 1958 and the dominant species is *Eleutheronema tetradactylum*. The fish breeds in the lake twice in the course of the year (June–July and January–February). Its fingerlings are available in overwhelming abundance in the lake practically throughout the year but only negligible numbers are caught in the outer channel. The June–July brood enters the commercial fishery in September and by December forms a mode at 112·5 mm. class and by July of the following year at 262·5 mm. class. The winter brood forms a prominent peak at 137·5 mm. class in the next July and attains a modal length of 233·5 mm. by December. Because of double breeding the length-frequency data are very complicated and difficult to interpret beyond one-year-old stages of either brood. The minimum size at maturity of the female was recorded as 347 mm.

Of a large number of species of perches recorded from the lake, commercially important species are *Lates calcarifer* (70·7%), *Gerres setifer*, (23·2%), *Sparus sarba* and *S. datnia* (both 1·4%). *Gerres setifer* breeds in the lake during the period May–September largely in the Southern Sector. New recruits (zero group) of the species form a very conspicuous mode at 53·3 mm. class in August. About a-year-old individuals averagely grow to a size of 112·5 mm. Minimum size at maturity was found to be 86 mm. Both the species of *Sparus* breed close to the lake mouth and sea in the months November–January. The minimum size at maturity of *S. sarba* female was found to be 213 mm. and the average 251·7 mm. New recruits (zero group) form a prominent mode at 82·5–98·5 mm. class in June. Mature individuals in December appear to be two-year olds. *Mystus gulio* formed 6·5% of the total fish production of the lake in 1958 and within the group it constituted 62·2%. *Osteogeneiosus militaris*, *Arius* sp. and *Plotosus canius* together formed 3·79% of the total production. Sciænids formed 6·88% of the total production in 1958. *Pseudosciæna albida* was the most dominant species which constituted about 90% of the production of sciænids. July and August were the maximum months of production of *P. albida*. The species is available in the lake throughout the year and the new recruits enter the commercial fishery in August–September. Ripe gonads are encountered in April–June.

Observations on temperature, turbidity, pH, salinity, total alkalinity, dissolved oxygen, PO_4, and SiO_2 were made in different sectors of the lake throughout the year.

Fish Pathology Investigations

24. *Studies on fish mortality in jute-retting tanks*

Investigations on the mortality of fish in jute-retting tanks were taken up in four experimental tanks at Nilganj. After a preliminary survey, the hydrological and biotic features of the tanks were studied and about 14,000 carp fingerlings were introduced. Plankton collections and observations on the condition of the fingerlings were made once every week. Chemical analyses of water samples were carried out at the Jute Agricultural Research Institute.

Different charges of jute were given in the tanks by the Institute. Mortality of fish first occurred in tank No. 4, then in tank No. 3 and finally in tank No. 2. It was found that fish in tank No. 4 died mainly due to lack of dissolved oxygen, caused by heavy jute charges. In tank No. 3, factors other than oxygen depletion were also responsible for the death of fish.

This has to be confirmed by aquaria experiments during the next jute season. Fishes in tank No. 1 were quite healthy in spite of three jute charges and they were netted in March 1959 and a total carp population of about 750 was estimated. The fishes had grown to satisfactory sizes and it is presumed that they survived due to lesser charges of jute and also because the charges were applied one after the other. From the results obtained it is possible to arrive at a maximum safe limit of jute charges for each mass of water. The results obtained have to be confirmed by another series of experiments during the next season.

25. *Studies on isopod infections*

Investigations on incidence of isopod parasites on estuarine fishes were taken up and regular observations were made at Diamond Harbour and Canning during the Winter Season. Data on infections on *Setipinna phasa*, *Harpodon nehereus*, *Trichiurus* sp. and cat-fishes were collected. It was observed that the parasites were few in number till middle of January and then moderate till end of February. There was a period of very heavy infection on *Setipinna* and *Harpodon* during the first week of February.

26. *Investigations on fish mortality in tanks*

The causes of mortality of fishes in three tanks in the suburbs of Calcutta were studied. The fish in a tank at Paikapara died due to lack of dissolved oxygen caused by abnormal consumption of oxygen by the bottom soil. This was further confirmed by the low density of bottom fauna. Fish in a Jheel at Barrackpore were found to have died due to lack of sufficient dissolved oxygen caused by large influxes of sewage and other polluted waters. In a tank at Chinapara Dhapa, an epidemic of fish mortality was reported and three types of pathological manifestations were observed. Many of the Catlas, Rohus and Mrigals were found infected with *Argulus* sp. and a good percentage of Catlas suffered from severe eye diseases (Exophthalmus and cataract). A few Catlas suffered from Dropsy also. Several collections were made and the specimens are being used for further studies.

CENTRAL INLAND FISHERIES
RESEARCH STATION,
Barrackpore.

B. S. BHIMACHAR,
Chief Research Officer.

SCIENTIFIC PAPERS PUBLISHED DURING 1958–59

1. K. H. ALIKUNHI. 1958. Observations on the feeding habits of young carp fry. *Indian J. Fish.*, **5**, 95–106.

2. ——— AND H. CHAUDHURI. 1959. Preliminary observations on Hybridization of the Common carp (*Cyprinus carpio*) with Indian carps. *Proc. Ind. Sci. Congr.*, Abstract, 1959.

3. B. S. BHIMACHAR. 1959. Inland Fisheries of India and their Problems. *Proc. Ind. Sci Congr.*, Presidential Address, 1–16.

4. H. CHAUDHURI. 1959. Experiments on hybridization of Indian carps. *Ibid.*, Abstract, 1959.

5. P. D. GUPTA. AND R. M. BHOWMICK. 1959. An interesting case of albinism in *Arius jella* Day from India. *Sci. & Cult.*, **28,** 283.

6. V. G. JHINGRAN. 1958. Observations on the seaward migration of *Mugil cephalus* Linnaeus from the Chilka Lake for breeding. *Curr. Sci.*, **27,** 181.

7. ———. 1959. On the breeding migration of *Mugil cephalus* from the Chilka Lake into the Sea. *Proc. Ind. Sci. Congr.*, Abstract, 1959.

—— AND R. D. CHAKRABORTY, 1958. Destruction of major carp fingerlings in a section of River Ganga and its probable adverse effects on fish production. *Indian J. Fish.*, **5,** 291–99.

9. S. JONES AND V. R. PANTULU. 1958. On some larval and juvenile fishes from the Bengal and Orissa Coast. *Ibid.*, **5,** 118–43.

10. M. M. KUNJU. 1955. Preliminary studies on the biology of the Palæmonid prawns *Leander styliferus* Miln. Edwards, with a note on its fishery in West Bengal, India. *Proc. Indo-Pac. Fish Council*, 6th Meeting.

11. M. T. PHILIPOSE. 1958. Contributions to our knowledge of Indian Algæ. II. Volvocales, unicellular forms. *Proc. Ind. Acad. Sci.*, **47** (5), 287–311.

12. T. V. R. PILLAY. 1958. Morphological and physiological characters of the blood of *Hilsa*, Hilsa *ilisha* (Hamilton) of the River Hooghly. *Ibid.*, **47,** 155–62.

13. ———. 1958. The biology and fisheries of the Hilsa, *Hilsa ilisha* (Hamilton), a review. *Proc. Indo-Pac. Fish. Council*, 6th Meeting.

14. ———. 1955. Land reclamation and fish culture in the deltaic areas of West Bengal, India. *The Progressive Fish Culturist*, **20** (3), 99–103.

15. ———. 1958. The biology of Hilsa, *Hilsa ilisha* (Hamilton) of the River Hooghly. *Indian J. Fish.*, **5,** 201–57.

16. —— AND A. N. GHOSH. 1958. A note on the Hilsa fisheries of Assam. *Jour. Bom. Nat. Hist. Soc.*, **55,** 174.

17. K. K. SAROJINI. 1958. Biology and fisheries of the Grey mullets of Bengal. II. Biology of *Mugil cunnesius*. *Indian J. Fish.*, **5,** 56–76.

18. ———. 1958. Observations on the occurrence, collection, acclimatisation, transport and survival of mullet seed in West Bengal (India). *Jour. Bom. Nat. Hist., Soc.*, **55.**

19. Y. R. TRIPATHI. 1957. Monogenetic Trematodes from fishes of India. *Indian J. Helminthology*, **9,** 1–149.

134-61. Printed at the Bangalore Press, Bangalore City, by T. K. Balakrishnan, Superintendent.

ERRATA

VOL. V (1)

Page No.	*Position* line	*For*	*Read*
47	20	(Table VIII)	(Table VII)
47	35	(Table VII)	(Table VIII)
49	10	(Table VIII)	(Table IX)
142	15	ones	Jones
153	12	Idoine	Iodine
156	5	so	also
173	9	Commom	Common
174	17	Polpulation	Population

VOL. V (2)

301 Plate V	4 last line	*Daya jerdoni* (Day)	*Lepidozygus tapeinosoma* (Bleeker)
314	30	arge	large
369	4	contoiner	container
438	19	R. Jones	S. Jones

ERRATA

VOL. VI (1)

Page No.	*Position* line	*For*	*Read*
30	9	Indian Union (Fig. 1)	Indian Union
34	20	before	for
47	29	*Daya jerdoni* (Day)	*Lepidozygus tapeinosoma* (Bleeker)
54	2	300–08	300–07
Plate I	3	miniatuer	miniature
157	19	611 *FNT*	6111 *FNT*
209	1	o not	do not
221	17	om	from

VOL. VI (2)

249	3	ofl ow	of low
284	8	bottom set gill nets	drift nets
286	5	do.	do.
287	15	bottom set gill net	drift net
292	5	bottom set gill nets	drift nets
296	3	do.	do.
348	4	microns	micrometer divisions
348	6	do.	do.
348	37	do.	do.
349	4	do.	do.
349	6	do.	do.
350	2	do.	do.

and should be in the form indicated in the examples given below. Titles of journals should be abbreviated as in the *World List of Scientific Periodicals* (London: Butterworth Publications Ltd., 3rd Edn., 1952).

Alcock, A. 1889 .. New and rare species of fishes from the Bay of Bengal. *J. Asiat. Soc. Beng.* **58,** 296–305.

Day, F. 1878 .. *The Fishes of India* (in two volumes). London, Bernard Quaritch.

Norman, J. R. 1947 .. *A History of Fishes* (3rd Edn.). London, Ernest Benn Ltd.

Regan, C. T. 1902 .. A revision of the fishes of the family Stromateidæ. *Ann. Mag. nat. Hist.* (7): **10,** 115–31, 194–206.

12. A slip-proof of each paper will be sent to the author, whose address should be given on the MSS. The corrected proof should be returned within a week to the Managing Editor, C.M.F.R.S., Mandapam Camp. As proof correcting involves heavy expenses, the cost of excessive corrections will be charged to the authors who are, therefore, advised to revise the MSS carefully and bring them to the final form before submission.

13. Authors, who receive 30 copies of reprints free, may order additional copies up to a maximum of 100 at the time of return of proofs; these will be charged for at cost price. 50 reprints will be supplied free of cost for papers appearing in the names of more than one author, with additional copies, not more than 100 per author, at cost price.

14. Blocks appearing in the *Journal* will become the property of the Government of India, although their loan for appropriate publication purposes will be arranged on request.

15. Views expressed in the papers published in this *Journal* represent only the views of the authors concerned. Neither the Government of India, nor the Editorial Committee accept any responsibility for these views.

EDITORIAL BOARD

1. The Fisheries Development Adviser to the Government of India, Ministry of Food and Agriculture (Agri.), New Delhi (*Chairman*).
2. The Chief Research Officer, Central Inland Fisheries Research Station, Barrackpore, *via* Calcutta.
3. The Chief Research Officer, Central Marine Fisheries Research Station, Mandapam Camp, South India (*Managing Editor*).

Annual Subscription Rs. 7/8
Price per Number Rs. 4

CONTENTS

PAGE

Alikunhi, K. H., Vijayalakshmanan, M. A. and Ibrahim, K. H. Preliminary Observations on the Spawning of Indian Carps, Induced by Injection of Pituitary Hormones 1

Hiralal Chaudhuri. Experiments on Induced Spawning of Indian Carps with Pituitary Injections 20

Raghu Prasad, R. and Ramachandran Nair, P. V. Observations on the Distribution and Occurrence of Diatoms in the Inshore Waters of the Gulf of Mannar and Palk Bay 49

Shaikhmahmud, (Miss) F. S. and Tembe, V. B. Study of Bombay Prawns. The Seasonal Fluctuation and Variation in Abundance of the Commercially Important Species of Bombay Prawns with a Brief Note on Their Size, State of Maturity and Sex Ratio 69

Tandon, K. K. Biology and Fishery of 'Choo Parai', *Selaroides leptolepis* (Cuvier and Valenciennes). I. Food and Feeding Habits 82

Jones, S. Notes on Eggs, Larvæ and Juveniles of Fishes from Indian Waters. V. *Euthynnus affinis* (Cantor) 101

Santimoy Banerjea and Motwani, M. P. Some Observations on Pollution of the Suvaon Stream by the Effluents of a Sugar Factory, Balrampur (U.P.) 107

Job, S. V. Growth and Calorific Approximation in the Speckled Trout (*Salvelinus fontinalis*) 129

Tampi, P. R. S. Utilization of Saline Mud Flats for Fish Culture—An Experiment in Marine Fish Farming 137

Karekar, P. S. and Bal, D. V. A Study on Maturity and Spawning of *Polydactylus indicus* (Shaw) 147

Raghu Prasad, R., and Ramachandran Nair, P. V. A Preliminary Account of Primary Production and Its Relation to Fisheries of the Inshore Waters of the Gulf of Mannar 165

Vasudeo, R. B. and Kewalramani, H. G. Transport of the Common Crab (*Scylla serrata*) in Living Condition 169

Deshpande, S. D. On the Fishing Experiments Conducted with a 10 ft. Beam-Trawl Net 174

Government of India, Central Marine Fisheries Research Station, Marine Fisheries P.O., Mandapam Camp, South India—Annual Report of the Chief Research Officer for the Year Ending 31st March 1959 . . . 187

Annual Report of the Central Inland Fisheries Research Station, Barrackpore, for the Year 1958–59 233

The drawing on the Cover Page depicts a tuna fishing scene off the island of Minicoy. The oceanic skipjack, Katsuwonus pelamis *(Linnaeus) which forms the most important fishery there is shown in the inset below.*

THE BANGALORE PRESS